LBRAITH & HAUGHTON'S

MANUAL OF

TIDES and CURRENTS.

GALBRAITH AND HAUGHTON'S SCIENTIFIC MANUALS.

MATHEMATICAL SERIES.

MANUAL

OF

TIDES AND TIDAL CURRENTS.

BY

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CONTENTS.

CHAPTER VII.

EXAMPLES ON THE RATE OF TIDAL STREAMS, AND ON SOUNDINGS.

TABLES.

PLATES.

MANUAL OF TIDES AND TIDAL CURRENTS,

&c. &c.

INTRODUCTION.

The dangers attending the navigation of the three channels which constitute the approach to the Atlantic from the ports of England have only received the attention they deserve of late years, partly in consequence of the great increase in the traffic of the Port of Liverpool, which is unfavourably situated with regard to the Atlantic, having Ireland right in the wind's eye; and partly in consequence of the fearful loss of life caused by the wreck of outward-bound emigrant vessels in winter.

Among the rules prescribed by the Board of Trade is one which requires all masters and mates of vessels to obtain a Certificate of Competency by examination before the local Marine Boards. These examinations include seamanship, navigation, and nautical astronomy; and in the case of Masters re-

quiring Certificates for the Coasting Trade, a knowledge of the Tides and Tidal Currents.

There can be no doubt that these examinations, limited in extent as they are, have already done much good, and promoted the acquisition of knowledge in the mercantile marine, without in any degree impairing the seamanlike qualities of British sailors. Much yet remains to be done, before the Home Passenger Trade can be considered in a satisfactory condition; but a beginning has been made, and progress will follow.

Among the subjects of importance to consider in the navigation of the dangerous seas that surround the English coasts, the most important are undoubtedly:—1, The state of the Compasses, particularly in Iron Ships; 2, The practical use of the Sounding Lead in approaching or navigating the channels in foggy or coarse weather; and, 3, The Laws of the Tides and Tidal Currents.

The first of these subjects has received of late all the attention it deserves, both from scientific and practical men, and will soon, it is to be hoped, be placed in a more satisfactory condition than at present.

The local authorities in several of the English Ports have made the question as to whether the Sounding Lead was used, or not, almost their only

test in deciding to regrant or to withdraw Certificates from masters and mates who have had the misfortune to run their vessels ashore from any cause; and in this way, we believe, the second subject has already received, at least, its due share of attention.

The importance of the third subject, viz., the Tides and Tidal Currents, is greatly underrated in the Mercantile Shipping Act of 1854, which merely provides that a Master in the Home Passenger Trade "*must understand how to make his soundings according to the state of the Tide.*" If we be not greatly mistaken, the ignorance of Tidal Currents is a most fertile source of the loss of ships, lives, and property in the Irish Sea and St. George's Channel; and yet, by the provisions of the Shipping Act, the Tides are considered as of importance only as they mislead in soundings; and the Tidal Currents, those treacherous and unseen enemies of the outward-bound ships, are ignored altogether.

How are we to account for the fact, so well known that it is almost proverbial in some of the western English Ports, that the wrecks on the Wexford coast almost always happen to outward-bound vessels with a fair wind? The compasses are not to blame, for the coast is, under such circumstances,

easily seen, and the headlands recognised. The sounding-lead could not give any information, for the same reason.

We feel satisfied that in the majority of these calamitous and unexplained wrecks, the commonly expressed notion of the sailor is correct, viz., that there is what he calls an *Indraught like*, on the coast; but which we would take the liberty of denominating a Tidal Current, whose laws are perfectly well known, and whose velocity and direction, at any moment of any day in the year, can be calculated and foreseen with the utmost precision.

We guard our ships with every precaution against the dangers of the winds and elements, which "blow where they list, the sound of which we hear, but cannot tell whence they come, or whither they go;" and yet, with singular fatality, we omit altogether the consideration of dangers arising from Tidal Currents, which can be reckoned on as certainly as the well-ordered motions of the Moon, which we rely on to guide our vessels across the widest oceans.

In the following pages we shall endeavour to demonstrate the great importance of a knowledge both of the Tides and of Tidal Currents to the navigator; and to apply the principles stated, in detail, to the Irish Sea and English Channel, illustrating the en-

tire subject by carefully-selected examples, and by reference to known cases of loss of ships, so as to render it easy of comprehension to all practical men.

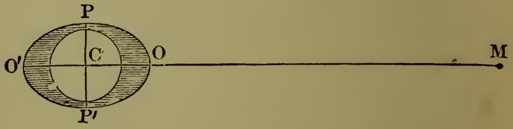
Throughout this treatise we shall refer to the "*Tide Tables for the English and Irish Ports*," published each year by the authority of the Admiralty, computed by Staff-Commander John Burdwood, R.N., and containing most valuable descriptions of the Tidal Streams or Currents by the late Rear-Admiral Beechy, and Lieutenant F. W. L. Thomas, R.N.

CHAPTER I.

TIDES AND TIDAL CURRENTS.

In speaking of the Tides we must carefully distinguish between the *Rise and Fall* of the Tide, and the *Flow and Ebb* of the Tide. They are both occasioned by the same cause, viz., the attraction of the Sun and Moon upon the waters of the sea. Of these two effects, the first, or Rise and Fall of the tide, is best known to landsmen; while the second, or Flow and Ebb of the Tide, causing currents in the water, is that which attracts the attention of sailors. It is of the greatest importance that both these movements of the water should be attended to in the navigation of narrow channels, such as the Irish Sea and the English Channel.

The accompanying diagrams show the manner in which the attraction of the Moon M produces the Rise and Fall, and also the Flow and Ebb of the Tide.



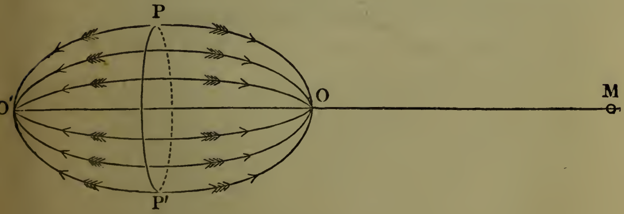
Since the Moon's attraction diminishes as her distance from the attracted point is increased, it is plain that the water at O is more attracted than the Earth at C; and again, that the Earth at C is more attracted than the waters at O′ on the opposite side of the Earth; but as the whole Earth, being solid, must move as one mass, and as the waters, being liquid, are free to follow the forces that act upon them, it is plain that the waters at O will *rise*, being drawn away from the Earth; and the waters at O′ will also *rise*, because the Earth is pulled

away from under them faster than they can follow. This accounts for the fact that there is always High Tide when the Moon passes the Upper or Lower Meridian of any place; in the first case, the High Tide is occasioned by the waters being actually lifted up from the Earth towards the Moon; and in the second case, the High Tide is caused by the earth sinking down under the waters, being drawn towards the Moon, which is at the time below the Horizon on the Lower Meridian.

As the waters are incompressible, and the total quantity of the sea covering the globe is constant, it follows that a rise in the waters at O and O′ must be accompanied by a corresponding fall in some other place; and accordingly we find that at the time of High Water at O and O′, there is Low Water at P and P′.

The Moon is in the *Zenith* of a spectator situated at the point O, and in the *Horizon* of the points P and P′, while she is directly under the feet, or in the *Nadir*, of a spectator situated at O′.

In order that the water should attain the shape represented in the figure, it is necessary that it should flow from P and P′ towards the points O and O′; this causes two distinct systems of currents, represented in the figure annexed—flowing from P, P′ in opposite directions towards O and O′.



If we therefore suppose the Earth to be covered with water, and the Moon to occupy any position M, and take

the point O vertically under the Moon, and draw the line MOO′, and also draw the circle PP′, at all points of which the Moon appears to be in the horizon; we may make the following statement:—

1. There is *High Water* and *Slack Tide* at the two points O and O′ for which the Moon is in the Zenith and Nadir.

2. There is *Low Water* and *Slack Tide* at all points of the circle PP′ for which the Moon is either rising or setting.

If the Moon were at rest, the waters of the sea, after having moved in the currents described, would settle down permanently into the figure of equilibrium represented in the diagrams, and all Tidal motions would cease. But as the Moon appears to move round the Earth in $24^h\ 48^m$, the points of High Tide O, O′ will travel after her, and the circle of Low Tide PP′ will also move round the earth. Hence we have *two* High and *two* Low Waters each Lunar day. In like manner the Tidal Currents represented by the arrows change their direction *four* times each lunar day, *Flowing* twice, and *Ebbing* twice; this is evident if we consider the Moon to move from M to the plane of PP′. The points O, O′ are now at Low Water, and PP′ High Water, and therefore the Tidal Streams are flowing from OO′ in opposite directions towards P and P′, just reversing the entire order of Tides; and this reversal of events happens at each point of the Earth's surface *four* times in each Lunar day, or $24^h\ 48^m$.

Hence at each place on the surface of the Earth the Tide should *Rise* and *Fall* twice during $6^h\ 12^m$ respectively; and *Flow* and *Ebb* twice for the same period of time.

In a practical sense the tide only rises and falls, flows and ebbs, for about $5^h\ 45^m$; as the rise and fall, flow and ebb of the water, is almost insensible for about half-an-hour at the time of High and Low Water and Slack Tide.

What has been just described is an accurate explana-

tion, so far as it goes, of what would happen if the sea covered the earth completely, and if there were no friction between the water and the bed of the sea; but as the sea is broken up into narrow channels, and impeded in its natural motion by the continents and islands of the land; and as the friction between the sea and its bed, and the coasts against which it washes, is very considerable, it follows that the phenomena of the Tides will be modified in a proportionate manner.

Hence, we never find the time of High Water to coincide exactly with the time of the Moon's southing, but always to follow it by an interval, greater or less, according to the retardation experienced by the water in passing from the open seas to the narrow channels which surround our coasts.

This retardation in the time of High Water is well shown on the map (Plate IV.), which represents a co-tidal map of the British Seas for the day of new Moon.

The red lines represent the lines along which it is High Water at the same hour of the day: they are called the V. o'clock, VI. o'clock, &c., Cotidal Lines.

By examining these lines we perceive that the Tide approaches the coast of Ireland from the west, and flows round both the north and south sides of the island, and that the High Water occurs at V. o'clock all along the West Coast of Ireland, and at all places to the eastward of the V. o'clock line the High Water does not occur until later.

As it is extremely important to understand this map in detail, we shall make some observations on it, which will be found of much use afterwards.

I should first state that the map gives no information whatever as to *Tidal Currents*, as the red lines only refer to the *simultaneous lines of High Water* or Co-tidal Lines. Throughout this treatise we have followed the plan of representing everything relating to High and Low Water by red lines on all the maps; and everything relating to Tidal Currents by black lines. It is hoped that the adop-

tion of this rule will serve to prevent much of the confusion likely to arise from confounding the Rise and Fall of the Tide with its Flow and Ebb.

Suppose that on the day of New Moon, she crosses the meridian of Greenwich at noon exactly, then, reckoning in Greenwich time, the following represents the progress of the High Water towards the Coasts of England:—

1. THE V. O'CLOCK TIDAL LINE.

At 5 P. M. it is High Water on the West Coasts of Galway and Kerry, along the south of Ireland, on the Coast of Cork and South-west of Waterford; at the Scilly Islands, Lizard Point, and along the South Coast of Devonshire; and at Ushant Island, off the Port of Brest, in Brittany.

2. THE VI. O'CLOCK TIDAL LINE.

At 6 P. M. the Line of High Water has become divided into two parts by the intervention of Ireland, and it is necessary to consider its northern and southern branches—

The Northern Branch causes High Water along the North Coast of Mayo, West of Donegal, and approaches Lewis Island on the West Coast of Scotland.

The Southern branch has in the meantime been divided by Cornwall into two portions, one of which enters the Irish Sea from the South, stretching in a curved line from Carnsore Point and Tuskar Rock in Wexford, to St. David's Head in Pembrokeshire.

The other branch proceeds up the English Channel, causing High Water at Plymouth, Axmouth, Guernsey, and Avranches, at the same time.

3. THE VII. O'CLOCK TIDAL LINE.

The *Northern Branch* of the Seven o'clock Tidal Line becomes divided into two portions, by the Western Islands of Scotland. in the same manner as the six o'clock

Tidal Line was divided by the county of Cornwall. Its upper portion proceeds towards the Orkney and Shetland Islands, which, however are not reached until past 8 o'clock: the lower portion causes High Water from the entrance of Lough Foyle, in Donegal East, to the Island of Islay on the South-west Coast of Scotland.

It will be observed by the aid of the map, that the line of High Water, after passing the Shetland and Orkney Islands, takes a southerly direction, and causes High Water successively from North to South along the east coasts of Scotland and England to the mouth of the Thames. It must, therefore, ultimately meet the branch of the Southern Tide which has been travelling up the English Channel. In like manner the lower branch of the northern High Water Line, entering the Irish Sea by the North Channel, proceeds southwards to meet the upper branch of the Southern Tide, which entered the Irish Sea by the South Channel at 6 o'clock.

Let us consider the meetings of these several branches in succession.

CHAPTER II.

MEETING OF THE TIDAL HIGH WATERS IN THE IRISH SEA.

By the meeting of the Tidal High Waters in the Irish Sea we mean the junction of the lines of High Water, from the North and South Channels, which takes place, as shown by the red lines on Plate IV., between 10 P. M. and 11 P. M., on the days of new and full Moon, throughout the greater part of the area of the Irish Sea, from Dublin and Holyhead on the south to Strangford Lough and Solway Frith on the north. It is necessary to follow carefully the course of the several co-tidal lines of High Water, both from the south and from the north.

THE VII. O'CLOCK TIDAL LINE.

Northern High Water.

The Northern High Water has not yet entered the Channel, but extends, in a curved line, from Innishowen Head, county of Donegal, to the Mull of Islay.

Southern High Water.

The Southern High Water, having entered the Irish Sea at 6 P. M., now stretches in a curved line from Greenore Point, county of Wexford, to Strumble Head, Pembrokeshire.

Rate of motion = 22 nautical miles per hour.

THE VIII. O'CLOCK TIDAL LINE.

Northern High Water.

This line causes High Water at Rathlin Island and the Mull of Cantyre, and runs rapidly up the centre of the North Channel, as shown in the map.

Rate of motion = 33 nautical miles per hour.

Southern High Water.

This line extends from Wexford Bay, past the tail of the Blackwater Bank, south of Bardsey Island, and terminates between Cardigan and Aberaeron, in Cardiganshire.

Rate of motion = 21 miles per hour.

THE IX. O'CLOCK TIDAL LINE.

Northern High Water.

This line has an arrow-shaped form, like the last, and extends from Fair Head, by the Maidens, to a point in the centre of the channel east of the Copeland Islands; whence it bends back northwards towards the Frith of Clyde.

Rate of motion = 26 miles per hour.

Southern High Water.

This line extends from Arklow, county of Wicklow, north of the Arklow Bank, to a point two-thirds across between Kingstown and Holyhead; and terminates at Aberdaron, Caernarvonshire.

Rate of motion = 23 miles per hour.

THE X. O'CLOCK TIDAL LINE.

Northern High Water.

The Northern line of High Water at 10 P. M. has passed the Isle of Man, forming a loop round it, so as to cause High Water at the same time on the East Coast of the county of Antrim, the Copeland Isles, the East and South Coasts of the Isle of Man, and the West Coast of the Mull of Galloway.

Rate of motion = 50 miles per hour.

Southern High Water.

The course of the Southern line of High Water at 10 P. M. has not been accurately traced by observations in the open sea; but it commences at Wicklow Head, and, passing the tail of the Kish Bank, sweeps round the Island of Anglesey, causing High Water at Linas Head and Great Orme's Head; it probably does not meet the Northern High Water until half-past 10 in the centre of the channel.

Rate of motion = 26 miles per hour.

THE XI. O'CLOCK TIDAL LINE.

The High-water Lines from the North and South Channels having met, between 10 P. M. and 11 P. M., in the centre of the Irish Sea, send off Eastern and Western branches of the XI. o'clock line, which approach the Coasts of England and Ireland respectively in the manner represented on the map, being nearly parallel to the coast line.

Eastern High Water.	*Western High Water.*
There is High Water at 11 P. M. from Burrow Head, Wigtonshire, to a point half-way between the mouths of the Dee and Mersey, near Wallasey.	There is High Water at 11 P. M. off the Irish coast, on a line from the mouth of Strangford Lough, through Lambay Island, to Howth Head.

The preceding facts serve to show the difference between the apparent progress of the High Water and the real progress or motion of the water itself, which latter is the Tidal Current or Stream. We see that the High Waters travel in opposite directions from both ends of the sea, at rates varying from 20 to 50 miles per hour, and meet in the centre between Anglesey and the Isle of Man, sending from their junction a united wave of High Water eastward towards Liverpool and Morecambe Bay, and another westward towards Dublin and Dundrum Bay.

In fact, this difference between High Water and the Tidal Stream cannot be too often or too much insisted upon. Nowhere in the Irish Sea does the Current caused by the Tide move faster than five knots per hour, and yet we have seen that the High Water nowhere appears to move slower than twenty knots per hour. In the open waters of the Indian Ocean and South Atlantic this is still more striking, as in those seas the High Water, unimpeded by islands or shoals, moves almost as fast as the Moon, and appears to travel at a rate little short of 1000 knots per hour.

If the Earth were completely covered by water, and there were no friction against the bottom, as supposed in Chapter I., it is easy to see that the High Water at the Equator would always appear to travel at the rate of 1000 miles per hour; for as the Moon appears to go once round the Earth in each day of 24 lunar hours, and as the circumference of the Earth is 24,000 miles, and as the High Water is always found directly under the Moon, it follows that the High Water would appear to move at

the rate of 1000 miles per hour; and yet, at the same time, the actual velocity of the Tidal Stream might be everywhere considerably less than five miles per hour.

In the next chapter we shall give the particulars of the Tidal Streams in the Irish Sea, which are of the highest importance to sailors. In the present chapter we are only concerned with the apparent movement of the Tidal High Water; and as the difference between this chapter and the next is highly necessary to understand, we shall endeavour, even at the risk of being thought somewhat tedious, to illustrate this difference by a few easily understood illustrations.

1st. When we see waves from the sea rolling towards a beach,—we speak of the motion of the wave as taking place in a single direction, viz., towards the shore,—if now we look at the motion of small floating objects, such as pieces of sea-weed, &c., we shall observe that they move forward on the crest of each wave through a few feet or inches, then stop, move backward again in the hollow of the succeeding wave, stop, and again move forward, as before, on the crest of the next wave. Here we see clearly the difference between the apparent wave-motion which takes place towards the shore, and the actual motion of the water, which is only forwards and backwards through a very small space.

Thus, let ABCD Plate VII. fig 1. represent a vertical section of two crests of waves and the intermediate hollow or depression: while the whole wave appears to move from the position AB to the succeeding position, CD, the particles of water, as is shown by the floating bodies, only move forwards and backwards, through a length AB or CD,—forwards on the crest of the wave, and backwards in the hollow, as is shown by the arrows in the section.

In this example, the motion of the wave from AB to CD illustrates the motion of the High Water of the Tide, while the motion of the particles in their elliptic paths represents the to-and-fro movement of the Tidal

Current, which always occurs in conjunction with the movement of the High Water, but ought carefully to be distinguished from it.

2nd. We shall take our second illustration from a totally different subject. Let us suppose the yellow fever, or measles, or any other *contagious* disease, to start from London and make its way through the country to Liverpool. In the case here supposed, in the strict sense of the word, nothing travels from London to Liverpool, but there is a succession of cases of fever propagated successively from hamlet to hamlet, and town to town, from London to Liverpool; and long before any individual case has become convalescent or terminated fatally, the disease itself may have reached the town of Liverpool. In this instance, the apparent progress of the fever through the country represents the apparent motion of the Tidal High Water; while the course of the disease in each individual afflicted with it, its early course, its crisis, progress towards convalescence, or fatal termination, represent the movements of the Tidal Currents. These latter always occur in conjunction with the movement of the Tidal High Water, but their motions and laws are different; they travel by different paths, at different rates, and produce quite different effects upon the surface of the water.

Practically speaking, it may be considered that the two Tidal High Waters, which enter the Irish Sea by the North and South Channels, respectively, on the days of new and full Moon meet at 11 P. M. along a curved line passing about eighteen miles to the south of the Isle of Man; and that the prolongations of this curved line, eastward and westward, would terminate a little to the north of Morecambe Bay, and in Dundalk Bay, respectively. As it is now High Water through the central portions of the Irish Sea, and at Liverpool and Dublin, and the adjoining ports and coasts, it must be Low Water along the Tidal lines, on which High Water occurred at 5 P. M. of the same day; and, similarly, when it

is Low Water in the central portion of the Irish Sea, or along the XI. o'clock Tidal line, it must be High Water along the V. o'clock Tidal line. This latter (V. Tidal line) sweeps along the south and west coasts of Ireland; and, therefore, there ought to be *two* points between it and the centre of the Irish Sea (or Head of the Tide), at which the water should neither rise nor fall. The existence of these two remarkable points is satisfactorily shown in Plate VI.; which represents, on a scale exaggerated as to height, the form of the surface of the Irish Sea and Altantic, north and south of it, taken from simultaneous observations round the coast of Ireland on the 1st July, 1851.

The stations at which the observations noted in this section were made are eight in number :—

1. Rathmullan, Lough Swilly;
2. Portrush, North Coast of county Antrim;
3. Cushendall, East Coast of county Antrim;
4. Donaghadee, county Down;
5. Kingstown, county Dublin;
6. Courtown, county Wexford;
7. Dunmore East, county Waterford;
8. Castletownsend, county Cork.

The various lines on the section represent the surface of the water at the several hours of the day, which was two days after the change of the Moon.

On examining these lines, it is easy to see that it was High Water between Kingstown and Donaghadee (or the Head of the Tide, where the two Tidal Waves meet) at the same time that it was Low Water between Dunmore and Castletownsend; and also Low Water at some point in the Altantic westward of county of Donegal. Also, that when it was Low Water at the Head of the Tide, between Kingstown and Donaghadee, it was High Water on the south coast of Cork and north westward of Donegal.

The twelve lines which represent the surface of the water at the several hours of the day also pass nearly

through *two fixed points:* one a little south of Courtown, and the other about half way between Portrush and Cushendall, at a point somewhat to the westward of Ballycastle, county of Antrim.

In fact, it is well known to all persons acquainted with the rise and fall of the tides on the Irish coast, that while the range of springs at the Head of the Tides of the Irish Sea near Ardglass, county of Down, is fully 15 feet, it diminishes both southwards and northwards from this point to Courtown on the south, where the range of Spring Tides is less than 2 feet; and to Ballycastle on the north, where the range of Spring Tides is only 3 feet. And again, when the two *nodes,* or minimum points, of Courtown and Ballycastle are passed, the range of the Tide increases to the south of Courtown, and to the north-westward of Ballycastle, respectively.

In Plate I. the red lines represent the range of Spring Tide in feet at the several points of the Irish Sea, and it is seen that they are arranged in the South Channel nearly in semicircles, whose centre is at Courtown and that the range of the Spring Tide increases progressively from West to East in crossing the Channel. If we follow the line of 15 feet range, we observe that it nearly fills up the circuit of Cardigan Bay; but that to the Southward and Eastward, beyond St David's Head, the range is successively 16, 17, &c., feet; and the same increase of range is evident to the Northward and Eastward, after passing Bardsey Island.

In fact, the range of Tide increases from Cardigan Bay up the Bristol Channel progressively from 15 feet to 47 feet, and from Cardigan Bay to Liverpool and Morecambe Bay from 15 feet to 32 feet.

Hence the centre of Cardigan Bay may be considered as the point of minimum range of Tides on the Welsh Coast, corresponding with Courtown on the Irish Coast; and it will be observed on Plate IV. that the VIII. o'clock High Water line joins these two points. In short, the VIII. o'clock High Water line is a nodal line

of the Tide Wave of the South Channel, and the range of Tide is least along this line; it is also the line of "*Tide and Half Tide*," as will be explained in the next section.

Returning now to the North Channel and Plate I., we see the red line of 4 feet Spring Tide range, passing from Fair Head, county of Antrim, to a point eastward of the Mull of Cantyre; the line of 3 feet Spring Tide range, which is the least range in the North Channel, passes from Ballycastle* to a point at the back of the Mull of Cantyre, where the Tide range is less than at any other point north or south of it.

This line is the nodal line of the Tides in the North Channel, and, like the corresponding line in the South Channel, nearly coincides with the VIII. o'clock High Water line.

This nodal line in the North Channel is also the line of "*Tide and Half Tide*."

* [I have been informed by my friend, the Rev. Robert Gage, Proprietor and Rector of Rathlin Island, that the mean range of Tide in Church Bay, on that island, is from 3 feet to 4 feet (F. and C.); but that in stormy weather its extreme range is from 9 feet to 2 inches, according to the direction of the prevailing wind.—S. H.]

CHAPTER III.

MEETING OF THE TIDAL CURRENTS IN THE IRISH SEA.

The Co-tidal lines of High Water enter the Irish Sea through both the North and South Channels, as explained in the preceding Chapter: the Southern High Water entering about an hour before the Northern High Water, or at VI. and VII. o'clock, respectively, at Full and Change of the Moon. The Tidal Streams or Currents which accompany the High Water have no such difference in their times of Flow and Ebb in any part of the Irish Sea; but are found to commence and cease simultaneously throughout the entire area of the sea.

Thus, although there is a difference of five hours, from VI. to XI. (Full and Change), between the times of High Water at Carnsore and Dundalk, St. David's Head and Liverpool, respectively, yet it is found that the current runs to the northward during the whole period of the Flow of the Tide, simultaneously through the whole of the Southern half of the Irish Sea and channel leading into it. And, in like manner, although there are four hours' difference in the time of High Water (from VII. to XI. Full and Change) between the mouth of Lough Foyle and Dundalk, and the Mull of Islay and Liverpool, respectively, yet the current sets to the Southward throughout the whole of the northern half of the Irish Sea and the Channel leading to it, during the entire period of the Flow of the Tide.

In the same way, during the Ebb of the Tide in the Irish Sea, the current sets throughout the whole Southern half of the sea simultaneously to the Southward, and through the whole of the northern half of the sea it runs simultaneously to the Northward. This important fact respecting the Tidal Currents was known in particular

instances by many sailors, who were aware that it was possible to have the advantage of the Tidal Current in the same direction during both the Flow and Ebb of the Tide in certain parts of the Irish Sea; for instance, it was well known that a vessel might start from Dublin Bay with a southerly wind, and Flood Tide setting to the north, and after passing Carlingford Lough find the Ebb Tide of the North Channel still running to the northward to help her out of the Channel.

But although individual sailors, here and there, were acquainted with these facts, they were not generally acknowledged, or their true laws known, until the late Rear-Admiral Beechey published the result of the numerous observations made by him in the Survey of the Irish Sea. In proof of this assertion, it may be sufficient to mention that in Mr. Nimmo's Sailing and Piloting Directions for the Irish Sea, the statements made and the rules laid down for the direction of the Tidal Currents are quite erroneous; and, if followed by masters of vessels, would often endanger their safety.

The black lines in Plate I. represent the course and rate in knots per hour of the Tidal Currents flowing into the Irish Sea both from the south and from the north.

It will be observed that the two systems of currents meet, and counteract each other, along a line joining St. John's Point, county of Down, with the Calf of Man; and again, to the eastward of the Isle of Man, they blend their streams together and flow in an united course to the Eastward, from Maughold Head into Morecambe Bay, in Lancashire. To the West of the Isle of Man, where the Flood Currents from the North and South Channels meet and destroy each other, there is still water at all times of Tide through an elliptical area marked on the map, in which no Tidal Current is visible; this space of no Tidal Current shows itself by the nature of its bottom, which is composed altogether of fine blue mud.

The line joining St. John's Point with the Calf of

Man, and Maughold Head with the centre of Morecambe Bay, is called the "*Head*," or "*End of the Tide*," and is remarkable for many reasons.

1st. It separates the two systems of Tidal Currents, from the North and South Channels, which here meet and destroy each other's motion.

2nd. The greatest Rise and Fall of the Tide takes place along this line in consequence of the meeting of the waters. The range of Tide at St. John's Point is 15 feet, and in Morecambe Bay, 31 feet, which are the greatest ranges on the Irish and English coasts of the Irish Sea.

3rd. The hour of High Water (and of Low Water) along this line of the Head of the Tide rules the course of the currents of Tide both in the North and South Channels. The following may be laid down as the Golden Rule of Tidal Currents in the Irish Sea; and was first stated distinctly by Rear-Admiral, then Captain, Beechey.

There is Slack Water throughout the whole Irish Sea and Channels from 40^{m} *before to* 40^{m} *after the Time of High and Low Water at the Head of the Tide, from St. John's Point to Fleetwood; during the Flow of Tide the Currents set simultaneously both in the North and South Channels towards the line of the Head of the Tide; and during the Ebb of the Tide the Currents run simultaneously both in the North and South Channels from the line of the Head of the Tide.*

This remarkable law was first proved to be true for the Southern half of the Irish Sea in Captain Beechey's paper, read before the Royal Society of London in 1848; in which he thus expresses himself:—

"The stream in the Southern Channel has been ascertained to move ***simultaneously in one vast current throughout*** ; running six hours nearly each way, at an average rate of from two to three knots per hour at the height of the springs, increasing to four knots and upwards near the banks and at the pitch of the headlands ; its ***times of Slack Water*** corresponding sufficiently near, for all practical purposes,

with the times of High and Low Water for the day at Morecambe Bay, or more correctly at *Fleetwood*, which is 12 minutes earlier than Liverpool."

The same rule prevails in the Northern Channel, where the stream also *sets in one vast current throughout*, but runs at a much more rapid rate, as is shown by the figures on the black lines in Plate I. In the narrow part of the Channel, between Fair Head and the Mull of Cantyre, the rate of the stream of Tide in springs is fully 5 knots per hour. The cause of this more rapid stream is shown in the two sections of Plate VIII. of the South and North Channels, which are carefully laid down to the same scale.

In the first section, which is drawn from Carnsore Point to St. David's Head, the figures denote the depth of the Channel in fathoms. At Spring Tides the whole body of water rushes through this section at the rate of 3 knots per hour; the greatest depth is 56 fathoms.

The second section is drawn from Tor Point, county of Antrim, to the Mull of Cantyre, and reaches a depth of 76 fathoms.

A remarkable channel, much deeper than other parts of the Irish Sea, exists between Wigtonshire and the county of Down. It is 28 miles long, $1\frac{1}{2}$ miles wide, and 145 fathoms deep. It is thus described by Captain Beechey:—

"The North Channel Stream, pressing more heavily on the Wigtonshire coast, has scooped out along this coast a remarkable ditch, upwards of 20 miles long, by only a mile in breadth, in which the depth is from 400 to 600 feet greater than that of the general level of the bottom about it."

We have already explained how the Northern and Southern Tidal Streams, meeting to the westward of the Isle of Man, produce permanent slack water, and cause the deposit of a fine blue mud, which the current is too feeble to carry off. The Eastern Branches of the Northern and Southern Tidal Streams, on the contrary,

meeting, not directly opposed, but under an angle, to the East of the Isle of Man, form by their union a current which sets rapidly, at the rate of from 1 to 2 knots per hour, into Morecambe Bay, where they cause an excessive deposit of mud, ooze, and fine sand, with only one deep channel leading through the banks, viz., the Lune Deep.

"Morecambe Bay, the grand receptacle of the Streams from both Channels, is notorious for its huge banks of sand heaped up in terrible array against the mariner unacquainted with its locality, and also remarkable for a deep channel scoured out by the stream, and known as the Lune Deep, which to the wary navigator is the great hidden beacon of his safety, and serves him, alike in fog or in sunshine, as a guide to his position and to a harbour of safety in case of need."—Beechey, *Phil. Trans.*, 1848.

It is to be observed that the black lines on Plate I. represent the course of the Flood Tidal Streams, and that the Ebb Tidal Streams are nearly similar, excepting that they press more upon the Irish coasts, and in some places near the Blackwater Bank actually flow across that Bank almost in a westerly direction. This circumstance renders an Ebb Tide always dangerous to vessels which have approached too near the Wexford Coast.

We have shown in the preceding Chapter that the line joining Courtown and Cardigan Bay, which nearly coincides with the VIII. o'clock Tidal High Water (Full and Change) is a line of least Rise and Fall of Tide, as the range of Spring Tides is greater than on this line at places both to the north and south of it; and that a similar line passes from Ballycastle to the East of the Island of Rathlin, and terminates in the Mull of Cantyre.

These nodal or VIII. o'clock High Water Lines are also lines of "*Tide and Half Tide*;" for when it is Low Water at the Head of the Tide, at V. o'clock, the stream commences to Flow both in the North and South Channels; i. e, three hours before High Water at the nodal lines; so that the Offing Tide begins to Flow at half-flood on shore; and in like manner the Offing Tide on the nodal lines begins to Ebb at half-ebb on shore, which is

the relation between the Offing and On-shore Tides, known to sailors as "*Tide and Half Tide.*"

These two lines are called the "Nodal" or "Hinge Lines" of the Tides of the Irish Sea, and possess the following properties:—

1st. The least Rise and Fall of the Tide takes place along these lines, which are thus the very reverse of the line called the Head or End of the Tide, along which the Rise and Fall of the Tide is greatest.

2nd. The quantity of water which passes during the Flow or Ebb of the Tidal Stream, into, or out of, the Irish Sea in a section drawn through these nodal lines is greater than the quantity of water passing through any other section of the sea; and, consequently, the Tidal Stream is, *ceteris paribus*, greater along these lines than in any other section of the channel.

The second statement which we have made respecting the nodal lines admits of easy proof. It will be seen that in the North Channel, the Tidal Stream is 4 to 5 knots per hour along the VIII. o'clock High Water line (Full and Change); this velocity of current is partly caused by the contraction of the channel, but not wholly, as a considerable part of it is due to the important fact, that *actually more water* flows through this section of the channel than through any other; and, accordingly, we find the velocity of the current diminishes rapidly, becoming only 2½ knots per hour between Belfast Lough and Portpatrick. In the South Channel, the velocity of the Tidal Stream along the VIII. o'clock High Water line (Full and Change) from Courtown to Cardigan Bay is 2½ knots per hour, which is a less velocity than that of the water at the entrance to the Channel, between Carnsore Point and St David's Head, where the Tidal Stream at Springs runs fully 3 knots per hour; but, on the other hand, the cross section of the Channel at Courtown, compared with that at Carnsore, is much greater than the inverse proportion of the velocities; and hence we see that here also the quantity of water passing

the nodal line is greater than that passing any other section of the channel either inside or outside that line.

But, it may also be proved directly that more water must pass through the section made by the nodal line than through any other section of the channel. Referring once more to Plate IV., containing the cotidal lines of High Water, it is evident that when it is High Water along the XI. o'clock line, it is Low Water along the V. o'clock line; and *vice versâ*, when it is Low Water along the XI. o'clock line, it is High Water along the V. o'clock line. From this consideration alone, it is plain that the VIII. o'clock line must be the line of least Rise and Fall of Tide, and be a nodal line or hinge of the Tide. In fact, the water at the XI. and V. lines at 8 P. M. has reached its mean level, falling at the first and rising at the second; and there must be some line intermediate between the XI. and V. where the water rises and falls least.

Let AB (Plate VII. fig 2) denote the mean Tide level of the Irish Sea; let *xy* represent its surface when it is Low Water at Liverpool; and *uv* its surface when it is High Water at Liverpool. Let PQ be the range of Tide at Liverpool, and RS at Wicklow, or any place intermediate between the Head of the Tide and the node at Courtown, at O. It is plain that no water passes through the section at Liverpool, for this is the Head of the Tide, and the opposite currents from the North and South Channels destroy each other's motion. Again, the water which passes the section at Courtown, or node of the Tide, must fill the area POQ, while that which passes Wicklow or any place intermediate between the Node and Head of Tide has only to fill the area PQSR. Hence more water passes the node than any point inside it.

Let us now take Carnsore, or any point outside the nodal line, and let LM be the range of the Tide at this place; while the water changes its level from *xy* to *uv*, the area LOM is poured into POQ without passing by Carnsore, and therefore, the water which actually passes the Carnsore section is only the difference between the

areas POQ and LOM, and is, of course, less than the area POQ, which represents the water that must pass by Courtown. In every case, therefore, a greater quantity of water passes through the nodal section than through any other section of the channel, inside or outside the nodal line.

The remarkable properties of the Head Line of the Tide and of the Nodal Lines may be summed up as follows:—

Head Line of Tide.	*Nodal Lines.*
From St. John's Point to Morecambe Bay.	1. North Hinge of Tide from Ballycastle to Mull of Cantyre. 2. South Hinge of Tide from Courtown to Aberystwith.
A. The Rise and Fall of Spring Tides is *greatest*. B. The Tidal Stream is *least*.	A. The Rise and Fall of Spring Tides is *least*. B. The Tidal Stream is *greatest*.

We shall conclude this Chapter by an extract from Rear-Admiral Beechey's account of the Tidal Streams at the Southern entrance into the Irish Sea, which will serve to show how completely the Tidal Currents are governed by the hour of High Water at the Head of the Tide, and how important an accurate knowledge of this fact must be, to insure the safe navigation of this dangerous channel.

"At the Smalls Lighthouse it is Slack Water 5 minutes before High Water at the entrance of Liverpool; the stream sets past the rock in a S. by W. ½ W. direction while the water is *falling* at Liverpool, and N. by E. ½ E. while it is *rising* there, veering to N. by E. during the two last hours of the tide. The strength of the tide is sensibly felt hereabout and all the way from the Smalls to Pembroke, running upwards of 3½ or 4 knots at the height of the springs. To the southward of the Smalls the stream sweeps round in a broad curve to the S. E., and enters the Bristol Channel while the water is

falling at Liverpool, and *vice versâ*, as before stated. The *entrance* of Liverpool is properly the standard to which the turn of the stream is referred; and wherever a reference is made to that place, it must be understood as being 18 minutes *earlier* than the time of High Water at St. George's Pier, to which the Tide Tables are adapted.

"On the Irish side, at the Saltees Lightship, for instance, the water is slack 22 minutes before it is High Water at Liverpool entrance. The stream sets W. S. W. from a quarter of an hour before High Water at Liverpool entrance to 1¼ hours after, and then W. N. W to Low Water. The flood or *Rising Tide* at Liverpool sets past the Saltees for the first 3 hours E. by S., then E. S. E. for the 2 next hours, and S. E. by E. for the last hour, when the tide slacks, as before, 22 minutes before High Water at Liverpool.

"From the Saltees Light-vessel to the Tuskar, the stream sets along the land, but towards Carnsore Point begins to tend to the northward on the flood, and finally sets sharply round that point into the Irish Channel, and must be carefully watched by vessels in this situation."

CHAPTER IV.

ON THE MEETING OF THE TIDAL HIGH WATERS AND TIDAL CURRENTS IN THE ENGLISH CHANNEL AND NORTH SEA.

The principles which we have already explained in detail respecting the Irish Sea are equally applicable to the English Channel, both as respects the High Water and Tidal Streams.

THE V. O'CLOCK TIDAL HIGH WATER LINE

Sweeps round the West and South Coasts of Ireland; runs (as is shown in Plate IV.) to the Scilly Islands; thence to Lizard Point; and, keeping along the shore, leaves the Devonshire Coast at Start Point, and crosses the Channel to the French Coast at the Isle de Bas.

THE VI. O'CLOCK TIDAL HIGH WATER LINE

Causes high water off the English Coast, but not on shore, from Plymouth to Portland Isle, and thence across the Channel west of Guernsey to Granville on the French coast.

THE VII. O'CLOCK TIDAL HIGH WATER LINE

Starts from Portland Bill, across the Channel to Cape La Hague.

THE VIII. O'CLOCK TIDAL HIGH WATER LINE

Lies very little inside the former at the coast, but advances up Channel considerably beyond the VII. o'clock line. Its course is from Durlstone Point, Swanage Bay, to a point half way between Cape La Hague and Cape Barfleur on the French coast.

THE IX. O'CLOCK TIDAL HIGH WATER LINE

Passes from Studland Bay, near Poole, along the south shore of the Isle of Wight, to Cape Barfleur; its central portions running rapidly up the centre of the Channel.

THE X. O'CLOCK TIDAL HIGH WATER LINE

Causes High Water off the shore from Culver Cliff, east of the Isle of Wight, to Beachy Head and Dungeness Point; thence across the Channel to Cape Antifern, near Havre. The central portion of this cotidal line extends up channel as far east as the line joining Boulogne and Folkestone.

THE XI. O'CLOCK TIDAL HIGH WATER LINE

Extends from the North Foreland to the East of the Port of Calais, and meets there the XI. o'clock Tidal High Water, twelve hours older than itself, which has come from the Atlantic down the east coast of Scotland, by the North Sea.

It is unnecessary to describe the course of the Co-tidal Lines which move round the north of Scotland, as their progress is sufficiently evident from Plate IV. It is plain from an inspection of that Plate that the XI. hour-line of High Water which meets the XI. hour-line (Full and Change) of the English Channel belongs to the Tide twelve hours older; and that, with this difference, the meeting of the tides in the Strait of Dover must produce the same effects upon the Channel Tides as the meeting of the Irish Tides between St. John's Point and Morecambe Bay.

As High Water occurs at the Head or End of the Tide in the strait of Dover at XI. o'clock (Full and Change), it will then be Low Water on the V. o'clock Lines, both in the English Channel and North Sea; and, *vice versâ*, when it is Low Water at Dover, it is High Water on

the V. o'clock Tidal Lines. Hence, we might expect to find both in the North Sea and English Channel, to the North and South of Dover, Nodal Points, or Hinges of the Tide, similar to those proved to exist at Courtown and Ballycastle in the Irish Sea.

Plate V., which is reduced from Captain Beechey, shows the existence and position of these Nodal Points. In this diagram the form of the surface of the water at every hour of the tide is shown, as in the corresponding diagram, Plate VI., which we have given of the form of the water along the Irish coasts. The head of the Tide is evidently situated somewhere between Dover and Beachy Head; and the Nodal Points are situated, *one* in the North Sea, near Yarmouth, on the Norfolk coast; and the *other* at Swanage, in Dorsetshire.

The same laws which we found to prevail at the Head of the Tide and at the Nodal Lines in the Irish Sea are also found in the English Channel and North Sea, and may be summed up as follows:—

I. HEAD OF THE TIDE.

1. The Rise and Fall of the Tide is greatest along this line, being 24 feet at Beachy Head, and 34 feet at Cayeux on the French Coast, a point corresponding with Liverpool, in the Irish Sea.

2. The opposing tidal Currents meet in a line across the Channel, which always lies between the North Foreland and Dunkirk, on the East; or Beachy Head and Point Ailly near Dieppe, on the West; and destroy each other's motion along this line, which is the Head of the Tide.

3. The hours of Low and High Water at Dover, or Head of the Tide, regulate the simultaneous Flow and Ebb of the Tidal Streams to and from Dover. This Flow and Ebb is simultaneous throughout a considerable portion of the English Channel and North Sea, as in the Northern and Southern divisions of the Irish Sea.

II. NODAL POINTS.

1. The Rise and Fall of the Tide is least at the Nodal Points near Yarmouth and Swanage respectively. This law is well exhibited in Plate V., where the range of Spring Tides at any point may be measured by means of the scale of heights annexed.

2. It can be proved by the same reasoning as was used in the case of the Irish Sea, that the greatest quantity of water will pass through the section joining Durlstone Point and Cape Barfleur in the English Channel; and the section from Yarmouth to the south of the Wells Bank; and, consequently, *ceteris paribus*, that the current of the water will be most rapid in those sections or Nodal Lines.

3. The Nodal or Hinge Lines of the Tides of the North Sea and English Channel coincide with the VIII. o'clock Co-tidal Lines, as at Courtown and Ballycastle in Ireland.

In the Irish Sea, the Head of the Tide is a line across the greatest breadth of the sea, while in the English Channel and North Sea, the Head of the Tide is a line across the narrowest section of the sea. This difference gives rise to some remarkable differences as to the meeting of the Tides in the two cases.

"In the Strait of Dover the line of meeting and of separation oscillates during each Tide between Beachy Head and the North Foreland (60 miles), in the following manner:—

"When the water of the shore at Dover begins to *fall*, a separation of the Channel streams takes place at Beachy Head; as the fall continues, this line of separation creeps to the eastward; at 2^h after Dover High Water it has reached Hastings; at 3^h, Rye; and thus it travels on until at Low Water, by the shore, it has arrived nearly at the line joining the North Foreland with Dunkirk. At this time the Channel streams on both sides *slack*; but the 60 miles from the Foreland to Beachy Head is still running to the westward. When the water begins to make again on shore, the Channel streams commence to run towards the Strait from both sides; and the line of separation again occurs at Beachy Head, and begins to travel again slowly to the eastward.

"Captain Bullock, to test the point of separation, anchored two

vessels a mile apart between Beachy Head and Dungeness, and found both vessels at the same moment to ride with their heads in opposite directions, in obedience to the streams which were then running opposite ways."—Beechy, *Phil. Trans.*, 1851.

As the streams of Tide in the English Channel and North Sea are governed by the Hour of High Water at Dover, and as there is Slack Water some minutes before and after High and Low Water at Dover, there will be a maximum velocity of current both in the English Channel and North Sea three hours before and after High Water at Dover.

The cause of the Tidal Currents running simultaneously to and from Dover is well worth considering. When it is Low Water in the Strait of Dover, it is High Water at the V. o'clock line at the entrance of the English Channel, and at the V. o'clock line from Flamborough Head to the Dogger Bank. There is, therefore, a slope of the water on both sides towards Dover, in consequence of which the Tidal Streams commence to flow simultaneously towards the Strait; after thus flowing for three hours, at 8 P. M., Full and Change, the currents both ways attain their greatest velocity, just at the moment when the surface of the water is exactly at its mean level throughout, and all slope destroyed. Yet the currents continue to flow towards the Strait of Dover by virtue of their acquired momentum, and actually run up hill for the last three hours of their course, until the water has acquired an equal slope in the opposite direction to that which it had when the flow commenced towards Dover. The slope of the water now causes the currents to ebb simultaneously for three hours, from the Strait of Dover into the North Sea and English Channel respectively, until the water is again level; after which the currents ebb up hill as before for the last three hours of ebb, in consequence of their acquired momentum.

In the Irish Sea, between Courtown and Liverpool, during the last half of the Flood Tide, the Stream has a slope gradually increasing from the level, to 12 inches in $4\frac{1}{2}$ miles.

CHAPTER V.

TIDES AND CURRENTS IN THE BRISTOL CHANNEL AND GULF OF ST. MALO.

In Plates II. and III. we have represented, after Captain Beechey, the southern half of the Irish Sea and Channel leading into it; and the English Channel to the Strait of Dover.

The Laws of the Tidal Currents already explained (*vide* Plate II.) hold good for the portion of the Irish Sea between the line joining Carnsore and St. David's Head in the South, and St. John's Point and Morecambe Bay in the North. Throughout this compartment of the sea the Flood Tide sets simultaneously to the North, and the Ebb Tide simultaneously to the South in one vast current, whose time of Flood, Slack Water, and Ebb, is regulated altogether by the Times of High and Low Water at the Head of the Tide. Outside the line joining Carnsore Point and St. David's Head, the Tides are more complicated, and follow the law of the Offing Tide along the South Coast of Ireland; and in the eastern portion of the sea, along the Western Coast of Cornwall, the Tidal Currents become very complicated, in consequence of the set of the water into the large bay formed by the Bristol Channel. It is, therefore, very important for the sailor to make himself acquainted with the laws of the Tidal Currents in this region of the sea, and more especially so, as these currents are very rapid, and appear to be very irregular, unless the true key to their motion be known.

In like manner (*vide* Plate III.), the Tidal Currents in the English Channel flow simultaneously towards the Strait of Dover, during *rising* water at that place, to the eastward of a line joining Portland Bill with Cape La Hague; and ebb from Dover simultaneously during the time the water is *falling* there. Outside, or to the

westward, however, of the line joining Portland Bill with Cape La Hague, the regularity of the Tidal Currents is interfered with by the currents flowing into and ebbing out of the Gulf of St. Malo, which exercises an influence on the currents of the western half of the English Channel, similar to that exercised on the waters of the Irish Sea, south of Wexford and Pembroke, by the Bristol Channel. A comparison of the two maps, II. and III,, leads to some conclusions of much interest in relation to their respective Tides. It is to be observed, that it appears, from Plate IV., that the IV. o'clock Co-tidal Line (Full and Change) causes High Water simultaneously at the outer or Atlantic entrances of both Channels.

COMPARISON OF THE SOUTHERN HALF OF THE IRISH SEA AND BRISTOL CHANNEL, WITH THE ENGLISH CHANNEL AND GULF OF ST. MALO.

Irish Sea.	**English Channel.**
1. *Atlantic Entrance.*	1. *Atlantic Entrance.*
From Cape Clear to the Scilly Isles ;	From the Scilly Isles to Ushant Isle ;
High Water at IV. o'clock (Full and Change).	High Water at IV. o'clock (Full and Change).
2. *Contraction of the Channel.*	2. *Contraction of the Channel.*
Carnsore Point to St. David's Head ;	Portland Bill to Cape La Hague;
120 miles from Entrance ;	117 miles from Entrance ;
High Water at VI. o'clock (F. and C).	High Water at VII. o'clock (F. and C.)
3. *Head of Tide.*	3 *Head of Tide.*
St. John's Point to Morecambe Bay ;	Dover to Boulogne ;
265 miles from Entrance ;	262 miles from Entrance ;
145 miles from Contraction ;	145 miles from Contraction ;
High Water at X.$\frac{3}{4}$ o'clock (F. and C.) ;	High Water at X.$\frac{3}{4}$ o'clock (F. and C.) ;
Range at Liverpool, 32 feet.	Range at Cayeux, 34 feet.

Irish Sea.	**English Channel.**
4. *Nodal Point.*	4. *Nodal Point.*
At Courtown; 150 miles from Entrance; High Water at VIII. o'clock (F. and C.); Range, 2 feet.	At Swanage; 150 miles from Entrance; High Water at VIII. o'clock (F. and C.); Range, 5 feet.
5. *Offset Bay.*	5. *Offset Bay.*
Bristol Channel; Range of Tide at Head of Offset Bay at Chepstow, 47 feet; From meeting of Tidal Streams in the Bristol Channel to the Atlantic Entrance at Land's End, 75 miles.	Gulf of St. Malo. Range of Tide at Head of Offset Bay at St. Malo, 47 feet; From the meeting of the Tidal Streams off Guernsey to the Atlantic Entrance at Brest, 75 miles.

It will be seen from the foregoing table that there is a striking resemblance in the Tides and Tidal Currents of the English Channel and of the southern half of the Irish Sea. As, however, the tides of the Bristol Channel are of more importance to English ships, at least in times of peace, than those of the Gulf of St. Malo, it will be useful to consider them separately.

TIDAL CURRENTS OF BRISTOL CHANNEL.

We have already explained that, in the contracted portion of the Irish Sea between the lines from Carnsore to St. David's, and St. John's Point to Morecambe Bay, the Tidal Stream flows to the North, while the Tide is *rising* at Liverpool; and ebbs to the South, while the Tide is *falling* at Liverpool. Plate II. represents the Tide rising at Liverpool, and flowing north in the Irish Channel; and it will be seen from the Plate that, while the Tidal Stream is *flowing* north in the Irish Channel, it is *ebbing* west from the Bristol Channel. At the

mouth of this Channel the water may be divided into two portions, the Northern and the Southern; of these, the Northern joins the Flood Tide of the Irish Sea, and runs rapidly round St. David's Head, forming the well-known and dangerous Goose Race; and the Southern portion runs to the south, along the Cornish coast, and turns abruptly round the Land's End, joining the Flood Tide, which is commencing to flow up the English Channel. For it is to be remembered that, as the times of High Water at Dover and Liverpool are the same, and also coincide with the times of Low Water at Land's End and the south coast of the county of Cork, the Flood Tidal Streams up the Irish Channel and English Channel will commence and cease at the same time.

On the other hand, while the tide is *falling* at Liverpool, the Ebb stream in the Irish Channel is running south, and the Ebb stream in the English Channel running west; and the Ebb stream of the Irish Channel turns to the east round St. David's Head, while the Ebb stream from the English Channel turns to the N. E. round the Land's End, and both combining form a great Flood stream, setting east into the Bristol Channel, and, at springs, raising the tide at Chepstow to between 50 and 60 feet, when aided by a south-westerly wind.

In fact, if the directions of the arrows in Plate II. be reversed, the Plate will accurately represent what happens while the tide is falling at Liverpool and Dover.

The following practical rules for the Bristol Channel Tides are useful to remember:—

1st. While the Tide is *rising* at Liverpool, and the Irish Channel Tidal Stream running north, there is a powerful *outflow* from the Bristol Channel, and a south-westerly current on the North Cornish coast.

2nd. While the Tide is *falling* at Liverpool, and the Irish Channel Tidal Stream running south, there is a powerful *indraught* into the Bristol Channel, and a north-easterly current on the North Cornish coast.

With regard to the important line of coast from the Scilly Islands to Ilfracombe, Captain Beechey makes the following observations:—

"While the stream from Scilly is setting to the *northward*, the stream from the Irish Channel will be found setting to the *southward*, and these streams meet off the entrance of the British Channel in about the parallel of 51°00 where both turn into that channel. As a general rule, in all the space eastward of a direct line joining Scilly and the Tuskar, the stream will be found running to the eastward towards the Bristol Channel, while the water is *falling* at Dover and Liverpool, and *vice versâ;* setting to the *north-east* on the southern side of the Channel, and to the *south-east* on the northern side. Such is the general set of the stream in this part of the sea, which I have given in general terms, to show that to the eastward of the line above mentioned a strong indraught towards the Bristol Channel will always be experienced while the water is falling at Liverpool, and *vice versâ.*"

It appears from the foregoing observations that the Bristol Channel is supplied with water from three distinct sources:—

1st. The whole of the Ebb, or outgoing stream of the eastern half of the Irish Sea, runs into the Bristol Channel, and forms the flood or ingoing stream of the northern half of that estuary.

2nd. The Offing Tide contributes its share to the central portion of the Bristol Channel.

3rd. The southern half of the Bristol Channel receives its waters from the northern half of the English Channel, the coast stream bringing the waters up from the Land's End and English Channel, in the same manner as the stream on the northern half did those of the Irish Channel.

TIDAL CURRENTS IN THE GULF OF ST. MALO AND WESTERN PORTION OF THE ENGLISH CHANNEL.

The contracted portion of the English Channel, so far as the Tidal Currents are concerned, is contained between a line from Portland Bill to Cape La Hague, and from

Dungeness to Cape Griznez. In this portion of the Channel the Tidal Flood Stream runs eastward while the Tide is *rising* at Dover, and runs westward while the Tide is *falling* at Dover.

Plate III. represents *Rising Tide* at Dover, and Flood Tidal Stream eastward up Channel. It will be observed that the eastern half of the waters of the Gulf of St. Malo are ebbing northwards, and setting rapidly round Cape La Hague to join the Flood Tidal Stream of the contracted portion of the Channel; while, at the same time, the Ebb Tidal Stream of the western half of the Gulf is setting rapidly to the westward along the coast of Britanny.

On the other hand, when the Tide is *falling* at Dover, the Channel Stream is ebbing westward, and the St. Malo Tidal Streams are flowing to the south-east into the bottom of the Gulf: if the arrows be reversed, the Plate will represent the *falling* Tide at Dover.

If a line be drawn from Portland Bill to Ushant Isle, and from Portland Bill to Cape La Hague, the English Channel will be divided into two regions, such that, when the tidal Streams ebb north-west in the first, they flow east in the second; and when they flow south-east in the first, they ebb west in the second.

The rules for the Tidal Stream in the Gulf of St. Malo are similar to those for the Bristol Channel.

1st. When the Tide is *rising* at Dover, there is a powerful *outflow* from the Gulf.

2nd. When the Tide is *falling* at Dover, the sailor should be on his guard against the great *indraught* past the Channel Islands into the Gulf, raising the Spring Tides at St. Malo to 50 feet.

CHAPTER VI.

APPLICATIONS OF TIDAL THEORY.

In the following Chapter, we have brought together a few cases, which illustrate the importance of a knowledge of the Tides, and the variety of uses to which that knowledge may be applied :—

1. **Loss of the Pomona, 1859.**—The Pomona was lost on the Blackwater Bank, in the spring of 1859. The following statement, made by the surviving mate, gives an idea of the circumstances under which the wreck took place.

Statement of the Third Mate.—" Stephen Kelly deposed that he was the third mate of the ship Pomona, of New York, of 1500 tons register, owned by the D. L. Line; and that he sailed from Liverpool on the 27th day of April, at 5 A. M., 1859, with a crew of 37 hands, including himself, bound to New York, with a cargo of general merchandize, and about 400 passengers, shipped by sundry parties of Liverpool, and consigned to sundry parties at New York. Did not know whether she was insured. Left Liverpool on the 27th April, at 5 A. M., wind south-east, fresh breeze. About 4 P. M., Holyhead bore about S.E. by E., distant about ten miles, steering then, I think, about a W. S. W. course. At midnight a strong breeze, ship under close-reefed topsails, lying to. Made a revolving light, and supposed it to be Tuskar; squared away with the ship, and steered a west course. Very soon after, she struck; could not tell where, but proved afterwards to be Blackwater Bank, where the sea very soon made a complete breach over her."

From the Liverpool Tide Tables, the following calculation is easily made, the result of which establishes the fact that the tide, so far from driving the ship on the Blackwater Bank, actually aided her in getting to the southward to the extent of five miles :—

High water at Liverpool, 27th April, 1859, . .	7h	27m P.M.
Deduct, ...	0	18
High water of head of tide, ...	7	9
Deduct time of passing Holyhead, ...	4	0
Before high water, ...	3	9

The vessel struck the bank at midnight, from which we find—

Time of striking, ...	12	0
High water, ...	7	9
	4	51

The Pomona, therefore, passed Holyhead 3 h. 9 m. *before* high water, and struck the Blackwater Bank at 4 h. 51 m. *after* high water. From the preceding results we have calculated,* that between 4 P. M. and midnight the tidal current carried the Pomona nearly five miles to the south. As the south end of the Blackwater Bank is ten miles to the north of the Tuskar, she was clearly fifteen miles out of her course, supposing her to have made no allowance for the tidal current.

It will be observed, that in the case of the Pomona the tide aided the vessel; but there is no reason to suppose that those in charge of the ship knew whether the current was with them or against them.

2. Loss of the Emperor, and grounding of the Lady Ebrington, on the Blackwater Bank (1857).— In the loss of the Pomona we gave an example of the kind of wreck, unfortunately, not unfrequent on the Wexford coast. The tidal current was only concerned indirectly in the loss of the Royal Charter and Pomona; but in the case of the two vessels to which we now ask attention, the tidal current was directly the cause of the

* The mode of executing this calculation, with the aid of Galbraith and Haughton's Tidal Cards, is given in Chap. vii.

disaster. The following account is taken from the Liverpool "Daily Post" of April 20th, 1857:—

"Peter George Mitchell was then called. He said—I was late master of the Barque Emperor; she was of wood, and 368 tons burthen; on the 28th of March last I sailed from Liverpool, with a general cargo, bound for Bahia; we had sixteen hands all told, and two passengers; she drew 15 feet forward and $15\frac{1}{2}$ aft; the cargo consisted of machinery for dead weight, and coals; she was towed out; the steamer left us three miles west of the Bell Buoy, at half-past 3 P. M., on Saturday; the weather was hazy, with drizzling rain; I ordered the ship to be steered N. W. by W.; I remained on deck, up and down, until we made the lights at Point Lynas; we had four compasses on board altogether, but only two in use—one in the brass binnacle, and one below; when off Point Lynas, I found a difference in the compasses, but I thought it was from the state of the weather; they varied a point and a half or two points; they were properly arranged by Messrs. Jewett the day before we left Liverpool; I found the variation to continue until we came near Holyhead; we got round her at a distance of four miles; the wind was S.E.; I braced my yards forward, the wind still continuing S. E.; *it was about midnight when we were off Holyhead;* we saw lights up to 3 o'clock in the morning; I ordered my chief officer to take bearings as long as he could see to do it; I never went to bed; I was in the clothes, when cast away, in which I left Liverpool; we steered the same course up till noon the following day; we made about six knots an hour on an average; we had full sails; *at 11 o'clock* A M. *we sighted land, which the chief officer reported as Bardsey Island;* I came up in the forenoon to see if I could take observations, but could not; the chief officer said we were 12 *miles from land;* I went to dinner at 1 o'clock; I left orders with the second officer to be sure to call me at the slightest alteration of wind or weather; at half-past 3 P. M. the second mate came down, saying the weather looked very dirty, and the wind was freshening, and inclined more to the south; I then went on deck, and ordered the hands to be called to shorten sail; the ship broke off at 3 to half-past; the ship broke off at W. S. W.; there was thick drizzling rain when I first came on deck, and I could not see farther than twice the ship's length; I considered she was at that time little more than amid channel; Bardsey Island was due east. The weather looking so dirty, I thought the wind would change, and I ordered the hands to reef the mainsail to tack; whilst so doing, she touched; this was about 4 o'clock; I ordered the hands down to put the ship aback; she answered her helm immediately, and came round; the wind was S. S. W.; her head came to the wind; she touched forward; she afterwards struck heavily aft, carrying away wheel, rudder-head, tiller-house, and everything abaft, excepting the upper works! She became

quite unmanageable. I ordered the hands to clew up the sails as quickly as possible, and ordered the carpenter to sound the pumps; he announced three feet in the well; it was reported to me shortly afterwards that pieces of wood were coming floating up at the side,—in fact, I saw them myself; I expected the masts to go by the board every moment. I ordered the cutter out; *the tide was about low water, the flood beginning to make;* I saw neither land, light, nor buoy; it was now half-past 5; the ship continued to beat heavily; I placed the two lady passengers in the cutter, having told them to dress in their warmest clothes; I then ordered the launch out; I left three to attend to her; I ordered the remainder to clew up the sails as snug as possible. I saw the men getting ready their bags; I called the officers, and we put the more helpless of the crew in the boats; I then held a consultation, and it was considered unsafe to stay any longer; we then ordered the men to put their clothes in the boats, and got in ourselves; I was the last; we thought we should be at sea all night in the boats; the ship reeled over before we had been out many minutes; we got to land in about half an hour; we saw light on shore, and made to it; we landed at Maurice Castle, fourteen miles from Wexford, to the east of Blackwater Head; next morning, on coming back, we found that the vessel had disappeared."

It was high water at the head of the tide on Sunday morning at 1 o'clock, when the Emperor had just passed Holyhead. From that time till 7 A. M., the tidal current helped her to the south twelve miles; and from 7 A.M. till 1. 15 P. M., the flood-stream carried her to the north again twelve miles. During this latter time, the wind being S. E., she made much more lee-way than Captain Mitchell thought, and was further to the west than was safe. The ebb stream now began to set southwards, and by a well-known law of the tidal currents in the neighbourhood of a bank, set almost S. W. over the tail end of the Blackwater Bank. To increase the mischief, it was three days after the new moon, and two days after the perigee, when the spring tides of the Irish Sea are most rapid and dangerous; and there can be little doubt that the ebb stream, setting from one o'clock to four o'clock P.M. across the bank with unusual rapidity, was the sole cause of the loss of this vessel. One of us expressed this opinion publicly in Liverpool, June, 1857, and has since seen no reason for changing his opinion.

The truth of this theory of the loss of the Emperor is conclusively established by the remarkable fact, that at the same time of the tide (viz., half ebb), on the night of the Sunday, on the afternoon of which the Emperor was lost, another ship, the Lady Ebrington, grounded on the Blackwater Bank, under precisely similar circumstances, and was with great difficulty saved from becoming a complete wreck.

3. Loss of the Irawaddy, 1856.—The case of the Irawaddy is very instructive, as showing the serious consequences that may result from the neglect of the tidal currents in the Irish Sea. The Irawaddy sailed from Glasgow on the 12th October, 1856, passed the Stack Light at 6 A. M. of the 13th, wind S. E.; and at 9. 30 P. M. the same evening, when all on board were satisfied that they had made the Cunny Beg Lightship, off the Saltees, the ship ran on the Blackwater Bank, twenty-two miles short of her supposed run, and ten miles short of the Tuskar. High water occurred at Dublin Bar on that night at 10.33 P. M., and at the head of the tide at 10.20 P. M., and low water occurred at the head of the tide at 4.8 P. M.

Between 4 o'clock and 9. 30, when the vessel struck, she was carried to the north 11½ knots,* a distance greater than that between the Blackwater Bank and Tuskar, on clearing which she could easily have made the Saltees with a south-east wind.

It is remarkable that the Emperor, the Lady Ebrington, and the Irawaddy, all struck the Blackwater Bank with a leading wind down channel. In such a case, the tidal currents are more dangerous than with a beating wind, as, with the latter, the captain will generally use the lead, and so become aware of his approach to the banks; while, with a leading wind, he naturally neglects the lead, and is unconsciously at the mercy of the tides, of which, in the majority of cases, he knows nothing.

* *Vide* Chap. vii., p. 60.

4. Use of Tidal Watch.—It occurred to us, on considering these cases, that a Tidal Watch might be advantageously used by vessels in the Irish and English Channels, in conjunction with Table I., in which we have calculated the rates of the Tidal Stream at any time before or after High or Low Water. This Table, and the uses to which it may be applied, will be fully illustrated in the following chapter.

The Tidal Watch is one which shows Lunar Hours, instead of Solar; i.e. each hour containing 60 lunar minutes, contains 62 ordinary or solar minutes. Any watch or chronometer may be converted into a Tidal Watch by compelling it to lose 2 minutes per hour, or 48 minutes in the day.

A ship, in the Irish or English Channels, provided with such a watch, set so as to show XII. o'clock at the time of High Water at Liverpool and Dover, would possess in this watch, used in conjunction with Table I., a valuable aid to the safe navigation of these narrow and dangerous seas.

Having set the Tidal Watch, in order to use the Table, the master must know from the Admiralty Tide Tables the *maximum* rate of the Tidal Stream at the ship's place; let him enter Table I. with this rate in knots per hour, and also with the hour given by the watch, and he will find the actual rate of the stream acting on his ship at the intersection of the two columns.

There is great danger in narrow seas, where the tide is strong, in trusting to the idea that, what the ship is drifted with the ebb, she is carried back with the flood, which is a common error. This may lead to fatal disaster,—as, for instance, in the case of a vessel that has arrived off the Blackwater Bank in mid-channel, with a south wind at the end of the ebb, and has experienced three floods since leaving Liverpool, and three ebbs, she will perhaps appear by her reckoning to be in her real position off the Bank; but she will for the next six

hours have a strong flood setting her up on the Bank, if she is on the Port Tack, which the master will make no allowance for, and will probably be lost.

In the next section we shall give a new method of finding, by construction, the amount of Tidal Drift between any two hours, for a given position of the ship.

5. On a Graphical Mode of Calculating the Tidal Drift of a Vessel in the Irish Sea or English Channel. —The change of level in the surface of tidal water, between two given hours, may be graphically calculated by the method given by Mr. Airy in his Treatise on Tides and Waves. Let a circle be described whose radius is *half* the Range of Tide, and painted on a vertical wall, the centre of the circle being placed at the mean Tide level; the tide, in its rise and fall, will cover and uncover equal arcs of this circle in equal times. If this circle be divided like the dial of a clock, XII. and VI. corresponding to the top and bottom of the vertical diameter, and tidal hours be used, the rise or fall of the water may be easily calculated.

In calculating the drift produced by the Tidal Stream, we are not given the total drift in six tidal hours, which would correspond to the Range of the Tide; but we have instead the maximum velocity of the Tidal Current at half-flood and half-ebb.

The following construction will enable us easily to calculate the Tidal Drift between two given hours:—

Let a circle be described whose radius is DOUBLE *the maximum rate of stream, and let this circle be divided into Tidal Hours; from the two given hours let fall perpendiculars on the diameter joining the hours of High and Low Water: the intercept between the feet of these perpendiculars, measured on the scale of the diameter, is the Tidal Drift required.*

This construction, which cannot be rapidly made, is superseded by Galbraith and Haughton's Tidal Cards,

the use of which will be fully explained in the next chapter. The proof, which is suited to mathematical readers only, is given in the note.

Note.—Let v denote the velocity of the Tidal Stream.
„ a „ maximum velocity of the same.
„ t „ time measured in Tidal Hours, from XII. o'clock.
„ $n = \frac{2\pi}{T}$,
„ T = twelve tidal hours ($12^h\ 24^m = 744^m$).

Then

$$v = a \sin nt,$$

therefore

$$ds = a \sin nt\, dt,$$

$$s = -\frac{a}{n} \cos nt + \text{const.}$$

$$0 = -\frac{a}{n} \qquad + \text{const.},$$

and, finally,

$$s = \frac{a}{n}(1 - \cos nt).$$

This is the Tidal Drift, measured from the commencement of the Ebb. It is evidently proportional to the versed sine of the Tidal Hour; and therefore the construction is proved, provided we can show that the radius of the Tidal Clock is *double* the maximum rate of the stream.

Calling H the Tidal Hour, we have

$$s = \frac{a}{n}(1 - \cos H),$$

$$= \frac{12^h.4}{2\pi} \times a(1 - \cos H),$$

$$= 1.973a(1 - \cos H);$$

and, taking this between any two Tidal Hours, we have

$$s - s' = \text{Tidal Drift} = 1.973a(\cos H' - \cos H).$$

For practical purposes, 1.973 is so nearly equal to 2, that the circle whose radius is *double* the maximum velocity a, will answer for the graphical calculation.

As an example of the use of the construction just given, let us take the case of the mail-steamer from Kingstown to Holyhead, at 7 P.M., November 11, 1861.

This steamer left Kingstown at $7^h\ 25^m$ Greenwich time, and expected to arrive at Holyhead at $11^h\ 25^m$. The High Water at the Head of the Tide took place at $6^h\ 42^m$ Greenwich time. Therefore the Tidal Hours of the steamer's departure and arrival are—

Departure from Kingstown, .	XII.43^m
Arrival at Holyhead, . . .	IV.43

Taking the maximum rate of stream between Kingstown and Holyhead at 3 knots per hour, and making the construction, we find that the Ebb Tide will drift the steamer 10.2 knots to the southward of Holyhead Harbour, unless a correction be applied in steering.

This is nearly the greatest amount of Tidal Drift that the Kingstown and Holyhead steamers are subject to. Their greatest drift is 10.4 knots, which will occur to the South, when their times of departure and arrival are I. and V. by the Tidal Clock; and 10.4 knots to the North, when their hours of departure and arrival are VII. and XI. by the tide. There is, therefore, in this four hours' run, which is made at the rate of 16 miles per hour, a possibility of the steamer finding herself, if she neglect the Tidal Stream, 12 miles to the north or to the south of Holyhead or Kingstown. In a fog, when the passage is delayed, it has sometimes happened that these steamers have arrived off Bray or Dalkey Sound, when they supposed they were close to the mouth of Kingstown Harbour.

CHAPTER VII.

As it is necessary for the sailor to be able to calculate the rate of the Tidal Stream for any hour of the day, and for any condition of tide, so that he may know the actual current acting on his vessel; and as it is also necessary for him to know the condition of the tide as to *rise or fall,* that he may be able to compare his actual soundings with those marked on the Admiralty Chart: we shall divide the Exercises on the Tides into two parts:—

I. Exercises on the Rate of Tidal Stream.
II. Exercises on Soundings.

Section I.—Rate of Tidal Streams.

To render the calculation of the rate of current easy for any hour, of any day, we have constructed Table I., which is to be used in connexion with the Admiralty Tide Tables of the English and Irish Ports, in the following manner:—

Rule I.

TO FIND RATE AND DIRECTION OF TIDAL STREAM.

(1.) *Find the time of high water at the head of tide.*

(2.) *If the time thus found be* BEFORE *the given time, subtract it from the latter; if it be* AFTER *the given time, subtract the latter from it.*

(3.) *With the Hour of Tide thus found enter the horizontal column of Table I., using in the vertical column the Rate of Stream found in the Admiralty Tables corresponding to the given place.*

(4.) *The intersection of the two columns gives the required* rate *for spring tide; if it be a neap tide, deduct one-third.*

(5.) *The* direction *of the current is given in the Admiralty Tables:* flood *tide, if the given time be* before *the time of high water of head of tide;* ebb *tide, if the given time be* after *the time of high water.*

In the following examples we shall confine ourselves to the Irish and English Channels.

A.—Examples on the Rate and Direction of the Tidal Stream in the Irish Channel.—As the time of high water at the head of the tides in the Irish Channel is 18^m before the time of high water at Liverpool, we must always subtract that amount from the Liverpool high water, given in the Admiralty Tide Tables.

1. A vessel finds herself, at 7 A.M. of the 10th of August, 1858, 5 miles east of the Tuskar Rock; required the rate and direction of the tidal current drifting her.

To work this example, we first turn to the Admiralty Tables, pp. 126–7, and find the rate at spring tides is 3 knots; by the Admiralty Tide Tables for Liverpool (p. 62), we find the 10th of August is a spring tide (because 9th August is the day of full moon), and that high water at Liverpool is at $11^h\ 57^m$; deducting 18^m, we find the time of high water at head of tide is $11^h\ 39^m$; we subtract 7^h from this, and find $4^h\ 39^m$ as the time before high water of head of tide; with this time we enter Table I. ($4\frac{1}{2}$ hours), and find in the column opposite 3 knots the rate of current, 2.13 knots per hour; and as it is *before* high water at head of tide, we say the direction is N. E. $\frac{3}{4}$ E.

The work of the example stands thus:—

Nearest high water at Liverpool, . .	$11^h\ 57^m$ A.M.
	18
High water at head of tide, ...	11 39
Subtract time of observation, ...	7 0
Before high water,	4 39

As it is a spring tide, we have nothing to deduct from 3 knots per hour, and therefore enter the Table with $4\frac{1}{2}$ hours and 3 knots, and find the answer,

Rate = 2.13 knots.
Direction = N.E. $\frac{3}{4}$ E., flood.

2. What is the rate and direction of tide acting on a vessel on the same day, in the same place, at 3 A.M.?

Nearest high water at Liverpool, .	$11^h\ 34^m$ P.M., Aug. 9.
	18
High water at head of tide, . . .	11 16 P.M., Aug. 9.
Subtract from time of observation,	3 0 A.M., Aug. 10.
After high water,	3 44

As $3^h\ 44^m$ is half way between $3\frac{1}{2}$ and 4 hours, we enter the Table with 3 knots, and find in the columns for $3\frac{1}{2}$ and 4 hours—

$3\frac{1}{2}$ hours, ...	2.88 knots.
4 hours, ...	2.58 „
Mean,	2.73 knots per hour.

And as the time is after high water, we must take the direction of the ebb tide from the Admiralty Tables. We therefore obtain—

Rate = 2.73 knots.
Direction = S.W. $\frac{3}{4}$ W., ebb.

3 On the 4th of October, 1857, at 6 P.M., a vessel was 5 miles east of the Arklow light ship: what was the rate and direction of the tidal current?

At p. 78 of Admiralty Tide Tables we find—

High water at Liverpool, ...	$11^h\ 40^m$ P.M.
	18
At head of tide, ...	11 22
Time of ship subtracted, ...	6 0
Before high water,	5 22

Since the rate of spring tides at this place, by the Admiralty Tables, pp. 126–7, is 3.6 knots, we enter the Table with $5\frac{1}{2}$ hours and $3\frac{1}{2}$ knots, and find—

Rate = 0.91 knots.
Direction = N.E. $\frac{1}{2}$ N., flood.

N. B.—As full moon occurred on the 3rd of October, we have no alteration to make from the spring tide rate.

4. On the 10th of October, 1857, a vessel was between Holyhead and Kingstown, five miles from Holyhead, at 7^h 15^m P.M.; find rate and direction of tidal stream.

High water at Liverpool, ...	4^h	7^m P.M.
		18
High water at head of tide, ...	3	49
Subtract from time of ship, ...	7	15
After high water,	3	26

We now enter the Table with $3\frac{1}{2}$ hours and 3 knots ebb from the Admiralty Tables, pp. 126-7, and find—

Rate at springs = 2.88 knots;

but as the 10th of October is a neap tide, we must deduct one-third, and obtain finally—

Rate = 1.92 knots.
Direction = S.W. $\frac{1}{4}$ S., ebb.

5. What is the rate and direction of the tidal stream on a vessel 5 miles west of the Skerry lighthouse, at 3 P.M. on the 14th of May, 1858?

High water at Liverpool, . . . ,	12^h	0^m noon.
		18
	11	42 A.M.
Subtract from time of ship, ...	3	0 P.M.
After high water,	3	18

We therefore enter the Table with 3 and $3\frac{1}{2}$ hours, and from the Admiralty Tables, pp. 126-7, ebb tide, 3 knots, and find—

3 hours, ...	3.00 knots.
$3\frac{1}{2}$ hours, ...	2.88 ,,
Mean,	2.94 knots per hour.

Rate = 2.94 knots.
Direction = W. $\frac{3}{4}$ S., ebb.

6. On the 5th of September, 1857, at 8 A.M., a vessel found herself near the Mull of Cantyre; what was the rate of the tidal stream?

High water at Liverpool, ...	11^h	52^m A.M.
		18
High water at head of tide, ...	11	34
Subtract time of ship, ...	8	0
Before high water,	3	34

Referring to the Admiralty Tables, pp. 130–1, we enter the Table with $3\frac{1}{2}$ hours and 5 knots, and find—

Rate = 4.80 knots, flood tide running S.E.

7. A steamer from Glasgow to Liverpool passed within 5 miles of Corsewall Point, on the 8th of December, 1857, at 2 P.M.; what was the rate and direction of the tidal current acting upon her?

High water at Liverpool, ...	4^h	36^m P.M.
		18
High water at head of tide, ...	4	18
Subtract time of ship, ...	2	0
Before high water,	2	18

From the Admiralty Tables, pp. 130–1, we find $1\frac{1}{4}$ knots for the spring tide at this point; therefore, entering the Table I. with $1\frac{1}{4}$ knots and 2 and $2\frac{1}{2}$ hours, we find—

2 hours, ...	1.08	knots per hour.
$2\frac{1}{2}$ hours, ...	1.20	,,
Mean,	1.14	,,

As the 8th of December is a neap tide, this rate must be reduced by one-third.

Rate = 0.76 knots.
Direction = S. $\frac{1}{4}$ E., flood.

8. What is the rate and direction of the tidal stream, between Sanda Island and Corsewall Point, at 5 miles from the former, at 4 P.M. of the 1st of July, 1858?

High water at Liverpool, ...	2^h	14^m	P.M.
		18	
High water at head of tide, ...	1	56	
Subtract from given time, ...	4	0	P.M.
After high water,	2	4	

From the Admiralty Tables, pp. 130–1, the rate of ebb tide at the given place is $1\frac{3}{4}$ knots. Entering Table I. with this rate, and two hours after high water, we find—

Rate = 1.50 knots.
Direction = N.W. by W., ebb.

9. At 5 minutes before 12, on the night of the 13th September, 1857, the iron ship Fusileer, laden with copper ore and bars, was wrecked in Bullslaughter Bay, half-way between St. Gowan's Head and Milford Haven, where the tide runs 3 or 4 knots at springs; find the rate of current at the time of the wreck.

High water at Liverpool, ...	7^h	31^m	P.M.
		18	
High water at head of tide, ...	7	13	
Subtract from time of wreck, . . .	11	55	P.M.
After high water,	4	42	

We enter Table I. with $4\frac{1}{2}$ hours and $3\frac{1}{2}$ knots, and find—

Rate = 2.48 knots.
Direction = S.E., ebb.

10. At 4^h 30^m P.M. of the 29th March, 1857, the Emperor struck and went down on the Blackwater Bank, off the Wexford coast; find the rate and direction of tidal stream at the time of the wreck.

High water at Liverpool, ...	1^h	28^m	P.M.
		18	
High water at head of tide, ...	1	10	
Subtract from time of wreck, ...	4	30	P.M.
After high water,	3	20	

Entering the Table I. with this time, and the rate, 3 knots, we find (by proportional parts)—

Rate = 2.92 knots.
Direction = S.W. ¾ W., ebb.

11. At $9^h\ 30^m$ P.M. of the 13th October, 1856, the Irrawaddy, from Glasgow, struck on the Blackwater Bank, where she was abandoned, and became a total wreck; find the rate and direction of the Tidal stream at the time of the wreck.

12. Find the rate and direction of the tidal stream at Rockabill, on the 14th July, 18—, at 6 A.M.

13. Find rate and direction of tidal stream 2 miles off the South Stack, in the Race of Holyhead, at 2 A.M. of the 16th September, 18—.

14. Find rate and direction of tidal stream 5 miles from Walney Island, west, at 11 A.M. of the 21st December, 18—.

15. Find the rate and direction of stream of tide, close to St. John's Point, on the 1st January, 18—, at midnight.

16. Find the rate and direction of tidal current 5 miles *west* of Peel, Isle of Man, on the 1st February, 18—, at noon.

17. Find the rate and direction of the tidal current 5 miles *north* of Peel, on the same day and hour.

18. Find the rate and direction of the tidal stream 5 miles south of the Mull of Galloway, on the 11th October, 18—, at 5 P.M.

19. Find the rate and direction of the tidal stream half-way between Burrow Head and the Point of Ayr, at noon of the 4th July, 18—.

20. Find rate and direction of tidal stream 5 miles north of Point of Ayr, at 4 A.M. of the 6th January, 18—.

21. Find the rate and direction of the tidal stream 5 miles south of Burrow Head, at 1 P.M. of the 17th March, 18—.

22. Find the rate and direction of the tidal stream half-way between the Point of Ayr and St. Bees Head, at 11 P.M. of the 1st April, 18—.

23. Find the rate and direction of the tidal stream half-way between the Mull of Galloway and the Copeland Isles, at 7 P.M. of the 6th of August, 18—.

24. Find the direction of the tidal stream at the Bahama light-ship, at 11 A.M. of the 1st December, 1858.

High water at Liverpool, ...	$8^h\ 2^m$ A.M.
	18
High water at head of tide, ...	7 44
Subtract from given time, ...	11 0 A.M.
After high water,	3 16

Referring to the Admiralty Tables, pp. 128–9, we find—

Course = N. by W. ¼ W.

25. Find the rate and direction of the tidal stream close in to Muck Island, at 9 A.M. of the 17th November, 18—.

B.—Examples on the Rate and Direction of the Tidal Stream in the English Channel.

1. What was the rate and direction of the tidal stream on the 22nd July, 1857, at 3 P.M., at the Admiralty Patch, in the centre of the Channel, westward of the line joining Ushant to the Land's End?

High water at Dover, ...	$11^h\ 50^m$ A.M.
Subtract from given time, ...	3 0 P.M.
After high water,	3 10

Turning to p. 134 (Admiralty Tide Tables), we find rate at springs is 1.50 knots. Entering Table I. with this rate, and $3^h\ 10^m$ after high water, we obtain—

Rate = 1.48 knots.
Direction = N.E. ¼ E.

2. What was the rate of tidal current at the Seven Stones, at 2 A.M. of the 16th January, 18—?

3. What was the rate and direction of the tide 10 miles due south of Prawl Point, at $11^h\ 30^m$ A.M. of the 17th November, 18—?

4. On the 14th September, 18—, a vessel was over Hurd's Deep, off Cape La Hague; what was the direction and force of the tidal current acting upon her at 5 P.M.?

5. Find rate and direction of tidal stream off Cape Barfleur, at midnight of the 17th December, 18—.

6. Find the rate and direction of the tide 4 miles W.N.W. of Cape La Hague, at 10 A.M., 1 P.M., and 7 P.M., of the 16th May, 18—.

N.B.—the Tidal stream is so rapid in this part of the entrance of the Gulf of St. Malo, that the determination of its rate and direction is particularly important.

7. The tidal streams from the North Sea and English Channel meet and destroy each other, at all hours of the tide, somewhere between the lines joining Beachy Head and Point Ailly, on the west; and the North Foreland and Dunkerque, on the east. (*Vide* Admiralty Tide Tables.)

Find the line of separation of the tides—

At 4 P.M. of the 16th May, 18—.
„ noon of the 14th June, 18—.
„ midnight of the 7th December, 18—.

8. If a vessel be anchored half way between Beachy Head and Dungeness, as in Captain Bullock's experiments (*vide* p. 33); at what hour of the 19th November, 18—, will she swing round to the tide?

9. At what hour of the afternoon of the 17th September, 18—, will the line of separation of the tides join Folkstone and Calais?

10. What is the rate and direction of the tidal stream off Cape Barfleur, at 2 A.M. of the 11th of June, 18—?

11. Find the rate and direction of the tidal stream, at $1^h\ 30^m$ P.M. of the 16th May, 18—, 20 miles westward of Ushant Isle.

TIDAL DRIFT.

The rate of the tide increases continually from slack water for three hours, when it attains its greatest value, and then continually decreases till the next slack water. The numerical calculation of the Tidal Drift, as depending on this varying rate (*vide* page 47), is too complicated for the practical seaman. We have fortunately been able to devise a simple mechanical method of solving the question by means of two Cards and a pair of parallel Rulers.

GALBRAITH AND HAUGHTON'S TIDAL CARDS.

On one of these Cards is engraved a circle, round the circumference of which are printed the twelve hours of the day, each hour being divided into intervals of five minutes.

On the other Card is drawn a square, whose side is equal to the diameter of the circle. The square is divided by a diagonal into two parts, with one of which we measure the Tidal Drift, with the other the Rise or Fall of the Tide.

At one extremity of the diagonal a string is attached, by means of which, when stretched across the scales A or B, any distance measured on them can be transferred to the parallel lines above them.

On the bevelled edge of the Ruler three or four fine lines should be cut with a knife about three inches apart, to serve as fixed marks against which the scales are to run.

Rule II.

TO FIND THE TIDAL DRIFT BETWEEN TWO GIVEN HOURS.

1. *Set the Ruler to the centre of the Clock-Card and the time of nearest High Water at the Head of the Tide; and if necessary, shift the Rulers until the two given hours are laid open to view.*

2. *Apply the scale* A *to the Ruler, and shift the Card until its left edge cuts the hour which lies to the right. Holding the Card in its place, shift the Ruler until one of the marks on it coincides with the Zero of the scale.*

3. *Holding the Ruler in its place, slide the Card to the left until the edge cuts the other hour, and note the point on the upper line of the scale which lies opposite to the mark on the Ruler.*

4. *Lift the Card: stretch the thread over this point, and observe where it cuts the line corresponding to the rate of tide at springs, as given in the Admiralty Charts or Tables.*

The distance marked off by the thread will be the number of knots the ship is drifted by the tide, or the

Tidal Drift between the two hours. The direction of the drift will depend on the flow or ebb of the tide.

If slack water falls between the two hours, the distance thus found will be the difference of two drifts—one forwards, the other backwards, or *vice versâ*, as the case may be. To obtain the fullest information as to the effect of the Tide on the ship's place, it will be generally useful to find both these drifts separately.

C.—Examples on Tidal Drift.

1. Find the Tidal Drift of the Pomona in the Irish Channel between 4 P.M. and midnight on the 27th April, 1859.

High water at Liverpool, ...	$7^h\ 28^m$ P.M.
Deduct, ...	18
High water at head of tide, ...	7 10

Applying the Ruler to the Clock-Card, and using the scale A, as directed, the distance run over is found to be $7\frac{1}{2}$ divisions: transferring this by means of the thread to the line marked III knots, which is the rate at springs, the drift is found to be 4.4 knots.

By the same method the drift between 4 P.M. and slack water at $7^h\ 10^m$, the time of High Water at head of tide may be found. The distance run over on the scale is 10.8, which, transferred by the thread to the line of III knots, gives 6.5 knots drift to the northward with the flood tide. From $7^h\ 10_m$ the drift with the ebb tide till midnight may also be found: the distance run over on the scale is $18\frac{1}{4}$ divisions, which, transferred by the thread, gives 10.9 knots drift to the southward.

It appears, therefore, that on the night on which the Pomona was wrecked, and in the interval between passing Holyhead and slack water in the Channel, she was carried with the flood $6\frac{1}{2}$ knots in a direction N. E. $\frac{3}{4}$ E., and from slack water till midnight with the ebb, 11 knots in a direction S. W. $\frac{3}{4}$ W.

2. Find the Tidal Drift of the Irawaddy between 4 P.M. and 9^h 30^m P.M. on the 13th October, 1856, off the Blackwater Bank.

High water at Liverpool, ...	$10^h\ 38^m$ P.M.
Deduct, ...	18
High water at head of tide, ...	$10^h\ 20^m$

The distance run over on the scale is 18.9 divisions, which on the line of III knots is converted by the thread into 11.4 knots of Tidal Drift. As 4 P. M. practically coincides with low water, it is evident that the whole Drift of 11.4 knots took place in one direction with the flood, *i. e.* N. E. by E.

3. Find the Tidal Drift in the Irish Channel on the 23rd August, 1865, between $3^h\ 10^m$ P. M. and $9^h\ 50^m$ P. M. (H. W. at Liverpool, $10^h\ 52^m$ P. M., Rate III knots).

Ans. 9.7 knots N. E.

4. Find the amount of Tidal Drift in Compartment XI of the North Sea, N. W. quarter, between 1^h P. M. and $4^h\ 30^m$ P. M. on the 10th February, 1865 (H. W. Dover 11 A. M.).

Ans. 5.8 knots N. E.

5. Find the Tidal Drift on the same day, and between the same hours, in the centre of Compartment III of the English Channel.

Ans. 9.6 knots N. W.

6. Find the Tidal Drift in the centre of the Baie de la Seine on the 29th August, 1865, between 11^h A. M. and $2^h\ 30^m$ P. M. (H. W. Dover $3^h\ 55^m$ P. M.).

Ans. 10 knots S. E. by E. ¾ E.

7. Find the amount of the Tidal drift of a vessel off Holyhead, between 3 P. M. and 5 P. M. on the 20th October, 18—.

8. Find the drift of a vessel, between the same hours, on the same day, off the Mull of Cantire.

9. How far will a vessel drift off St. David's Head, between $10^h\ 10^m$ A. M. and $10^h\ 30^m$ P. M., of the 16th December, 18—.

Section II.—Soundings.

As the soundings marked on the Admiralty Charts are all referred to low water of ordinary spring tides, the depth of water occurring at any point marked on the Charts will always exceed the Admiralty sounding, except when the time of observation happens to be low water of greatest spring tides. It is necessary, therefore, for the sailor to be able to calculate the difference between the actual depth of the water and the depth marked on his map (which is the depth at low water of ordinary spring tides).

Two classes of questions may be proposed in reference to this subject: *firstly*, to find the depth of water at a given place and hour; *secondly*, having observed the actual depth, to find the Admiralty sounding corresponding to it, and the place on the Chart. Both these classes of questions require us to know the *time* of high water and the *range* of tide on the given day; and we shall, therefore, commence our examples by some questions illustrative of the *time* and *range* of tide.

D.—To find the time of High Water and the Range of Tide, on a given day, at any one of the Ports of Reference given in the Admiralty Tide Tables.

The ports of reference are twenty-four in number, and the times of high water are given for each day of the year at each of them. To find the range of the tide, the following Rule is to be adopted:—

Rule III.

1. *Subtract the half mean spring range of the port from the height of tide for the day, given in the Tables.*
2. *Double the difference is the range of tide.*

EXAMPLES.

1. Find the half range of the morning tide at Liverpool of 9th May, 1858.

High water (Admiralty Tables), . . .	21^{ft}	5^{in}
Subtract mean half range, ...	13	0
Half range for day =	8	5

2. Find the half range of evening tide at Liverpool of 24th May, 1858.

High water, ...	23^{ft}	0^{in}
.	13	0
Half range for day =	10	0

3. Find the half range of evening tide at Liverpool of 24th April, 18—.

4. Find the interval from high water at 5 P. M. of 19th May, 1858, at Liverpool.

Time of high water, ...	4^h	4^m P.M.
Subtract from, ...	5	0
Time *after* high water, =	0	56

5. Find the time from high water at 7 A. M. of the 19th December, 1858, at Liverpool.

Time of high water, ...	9^h	43^m A. M.
Subtract, ...	7	0
Time *before* high water =	2	43

6. Find the range of tide at Dover, on the afternoon of the 16th March, 18—.

7. Find the range of tide at Thurso, on the morning of the 24th April, 18—.

8. Find the range of tide at Holyhead, on the morning of the 2nd of October, 18—.

9. Find the morning and evening ranges of tide at Weston-super-Mare, on the 24th of October.

10. Find the range of the morning tide at the London Docks, on the morning of the 31st January, 18—, on which the Great Eastern was floated off into the river.

11. What is the interval from high water at Duncannon Fort (Waterford), at 3 P. M. of the 16th March, 18— ?

12. Find the time from high water at Harwich, at 4^h 16^m A. M. of the 17th Deeember, 18—.

E.—To find the time and Range of Tide, at British and Irish Ports, not Ports of Reference.

Rule IV.

If the place at which the time *and* range *of tide are required be not a standard port, it is to be referred (if in the west of Europe) to a standard port, by adding or subtracting a certain constant to the time and range of that standard port, as directed in the Tables.*

In the Admiralty Tables will be found upwards of 200 ports in Europe for which standard ports of reference are given, and the time which is to be added or subtracted to or from the time of high water at such standard port.

By this means the determination of the time of high water seems so simple as to require no further explanation; but the mariner is frequently perplexed in carrying out this simple process, unless further explanation is afforded. In adding to the time at a standard port the constant given in the Tables, a morning tide frequently becomes an afternoon tide, and an afternoon tide frequently becomes a morning tide for the next day. When also the constant is subtractive, the morning tide at the standard port frequently becomes an afternoon tide of the day before, and the afternoon tide of the given day becomes a morning tide. If thus we find that the morning tide at the standard port becomes an afternoon tide, by applying the additive constant, the afternoon tide of the day before must be employed to determine the time of high water in the morning. When also the constant is subtractive, if the afternoon tide becomes a morning

tide, the morning tide of the succeeding day must be employed to determine the time of the afternoon high water for the given port.

It also frequently occurs that when there is only one high water at the standard port, there are two at the given port; and also when there are two high waters at the standard port, there is frequently but one at the given port. In the first case, when at the standard port there is only an afternoon high water, at the standard port the morning time of high water for the succeeding day must be employed to determine the afternoon time, and the afternoon time for the given day will give the morning tide required, if the constant be subtractive; but when the constant is additive, the morning tide becomes an afternoon, and the afternoon of the day before becomes the morning tide.

If the morning tide, by adding a constant, is more than twelve hours, and thus becomes an afternoon tide, but the afternoon tide of the day before remains less than twelve when the constant is added, there is no morning high water that day at the required port; so also if, when the constant be added to the morning time of high water, the time is less than twelve, but when added to the afternoon time is greater than twelve, there is only a morning time of high water at the given port. If, also, when the constant is subtractive, the afternoon require to be augmented twelve hours, but the time for high water at the standard port is less than the constant, there is only a morning high water; but if the afternoon time of high water at the standard port be more than the constant, but the morning tide less, there will be only an afternoon time of high water at the port required.

F.—Examples on the Time of Tide at British Ports, not Ports of Reference.

1. August 19, 1858; required the times of high water at Ballycastle Bay.

High water at Belfast,	6^h 18^m A.M.	7^h 1^m P.M.
Constant	− 4 35	− 4 35
Answer,	1 43 A.M.	2 26 P.M.

2. May 13, 1858; required the times of high water at Aberdovey.

High water at Pembroke,	5^h 40^m A.M.	6^h 4^m P.M.
Constant	+ 1 48	+ 1 48
Answer,	7 28 A.M.	7 52 P.M.

3. July 2, 1858; required the times of high water at Portland breakwater.

High water at Portsmouth,	3^h 19^m P.M.	3^h 39^m A.M., July 3.
	12 0	12 0
	15 19	15 39
Constant	− 4 40	− 4 40
Answer,	10 39 A.M.	10 59 P.M.

4. Sept. 11, 1858; required the times of high water at Inverness.

High water at Queenstown,	7^h 1^m A.M.	6^h 44 P.M., Sept. 10.
Constant	+ 7 17	+ 7 17
	14 18	14 1
	12 0	12 0
Answer,	2 18 P.M.	2 1 A.M.

5. July 27, 1858; required the times of high water at Limerick.

H. W. at Dover, July 27	0^h 4^m P.M.	0^h 23^m A.M., July 28.
	12 0	12 0
	12 4	12 23
Constant	− 4 56	− 4 56
	7 8 A.M.	7 27 P.M.

6. August 19, 1858; required the times of high water at Workington.

H. W. at Brest, Aug. 19,	11^h	47^m A.M.	11^h	1^m P.M., Aug. 18.
Constant +	7	17	+ 7	17
	19	4	18	18
	12	0	12	0
	7	4 P.M.	6	18 A.M.

7. August 16, 1858; required the time of high water at Aberystwith.

H. W. at Galway, Aug. 16,	9^h	11^m A.M.	8^h	48^m P.M., Aug. 15.
Constant +	2	56	+ 2	56
	12	7	11	44 P.M. Aug. 15.
	12	0		
	0	7 P.M.		

No morning tide on the 16th August.

8. October 16, 1858; required the time of high water at Barnstaple.

High water at Weston-super-Mare,	0^h	14^m	0^h	58^m P.M.
Constant	− 0	31	− 0	31
			0	27 P.M.

No morning tide.

9. January 16, 1858; required the time of high water at Ramsey.

High water at Holyhead,	10^h	52^m A.M.	11^h	9^m P.M.
Constant +	1	1	+ 1	1
	11	53 A.M.	0	10 A.M., Jan. 17.

No afternoon tide on the 16th of January.

10. January 13, 1858; required the time of high water at Glasgow.

High water at Greenock,	10^h	51^m A.M.	10^h	27^m P.M., Jan. 12.
Constant +	1	17	+ 1	17
	12	8	11	44
	12	0		
	0	8 P.M.		

No morning tide at Glasgow, January 13.

G.—Examples to find the Time of High Water at Foreign Ports.

In the Admiralty Tide Tables, there are given the times of high water at full and change, by which we are enabled to calculate approximately the time of high water on each day. The constant is determined by taking Brest as the standard port, at which place the time of high water, full and change, is $3^h\ 47^m$. The difference between the Time at the given Port and at Brest will be the constant, to be employed as in the last Rule, except if there be a great difference of longitude; in which case the correction for the moon's meridian passage must be employed, since for the greatest longitudes this correction may amount to half an hour. If the longitude does not exceed five degrees, it may be neglected, since it can scarcely make more than a minute's difference. It must be also remarked that Brest is nearly five degrees west of Greenwich, and, therefore, in making this correction, five degrees should be subtracted, if the longitude of the place be east; or added, if it be west.

1. September 1, 1858; required the time of high water at Victoria River, long. 130° E.

High water, full and change, at Victoria River, ...	7^h	15^m
Ditto, Brest, ...	3	47
Constant to be added,	+ 3	28

Moon's transit, Sept. 1,	6^h	7^m	Long. of Victoria River,	130° E.
„ „ 2,	7	10	+	5
	1	3		135

Below 63^m and against 135° long, in Table IV., we find 24^m to be subtracted in E. long.

High water at Brest,	$8^h\ 41^m$ A.M.	$9^h\ 20^m$ P.M.
Constant	+ 3 28	+ 3 28
	12 9	12 48
Corr. for long.	− 0 24	− 0 24
	11 45 A.M.	12 24
		12 0
		0 24 A.M., Sept. 2.

No afternoon tide.

2. June 10, 1858; required the time of high water at Nelson, New Zealand, long 173° E.

High water full and change at Nelson, . .	$9^h\ 50^m$
Do. do at Brest, . .	3 47
Constant to be added,	+ 6 3
Moon's transit, June 10, ...	$10^h\ 43^m$
Do. June 9, ...	9 42
	1 1

Below 61 minutes, and against 173, Table IV., 28 minutes.

High water at Brest,	$2^h\ 2^m$ A.M	$2^h\ 27^m$ P.M.
Constant	+ 6 3	+ 6 3
	8 5	8 30
Corr. for long.	− 0 28	− 0 28
	7 37 A.M.	8 2 P.M.

3. April 13, 1858; required the time of high water at Cape Virgin, Strait of Magellan, long. 68° W.

High water at Cape Virgin, change and full,	$8^h\ 30^m$
Do. do. at Brest,	3 47
Constant	+ 4 43
Moon's transit, April 13, ...	$11^h\ 32^m$
Do. April 12, ...	10 44
	0 48

Below 48 minutes, and against 70°, Table XVI., 9 minutes.

High water at Brest,	3^h	4^m A.M.	3^h	23^m P.M.
Constant,	+ 4	43	4	43
	7	47	8	6
Corr. for long.	+ 0	9	+ 0	9
	7	56 A.M.	8	15 P.M.

II.—To find the depth of water at a given time and place.

To find how much we must add to the Soundings on the Admiralty Charts, we must use Table II., which contains the height, above or below half tide, for a given *half range of tide, and time from high water:—*

Rule V.

(1.) *Having found the time from high water (less than 6 hours) before or after, and the half range of tide for the given day, and having entered the Table with these data, and found the figure corresponding to their intersection in the Table; add or subtract (as directed in the Table) the figure so found to or from the mean half range of the Admiralty Tables.*

(2.) *The result thus found is the excess of the sounding observed above the sounding recorded on the Chart, and should be added to the Admiralty sounding to find the real depth of water.*

EXAMPLES.

N. B.—As the Admiralty Chart of the Port of Liverpool refers its soundings to a datum line 2 feet below the mean low water of spring tides, it is to be observed in the subsequent examples for Liverpool, that 2 feet is to be added to the depth of water found by the preceding Rule, in order to ascertain the exact depth at a given time.

1. Required the height of the tide at Liverpool above the mean low water of spring tide on 6th April, 1858, A.M., at 2^h 4^m *after* high water.

High water, ...	19^{ft}	0^{in}
	13	0
Half range for day =	6	0

Entering the Table II. with 6 feet and 2^h 4^m, we find—

Height, ...	3^{ft}	0^{in}
Add to, ...	13	0
Above mean level of spring tides,	16	0

2. Required the height of the tide at Liverpool above mean low water of spring tides on 15th April, A.M., at 4^h 8^m *after* high water.

High water, ...	27^{ft}	6^{in}
	13	0
Half range for day,	14	6

Entering the Table with $14\frac{1}{2}$ feet and 4^h 8^m, we find—

Height, ...	7^{ft}	3^{in}
Subtract from, ...	13	0
Above mean level of spring tides,	5	9

3. Required the level of the tide at Liverpool above mean low water of spring tides on 15th April, 1858, A.M., at 5^h 41^m after high water.

High water, ...	27^{ft}	6^{in}
	13	0
Half range for day,	14	6

With this half range and 5^h 41^m, enter Table II., and we find—

Height, ...	14^{ft}	0^{in}
Subtract from, ...	13	0
Below mean level of spring tides,	1	0

4. The depth of water marked on the bar of the Victoria Channel, on the Admiralty Chart, is 11 feet. What was the depth of water on this bar at 2 A.M. of the 11th July, 1858?

(1). *Find time from high water.*

Time of high water, . . .	= 10^h	50^m	P.M. of 10th.
Subtract from, ...	2	0	A.M. of 11th.
Time *after* high water,	3	10	

(2). *Find half range for day.*

High water	= 25^{ft}	5^{in}
Subtract, ...	13	0
Half range for day,	12	5

Enter the Table II. with these numbers, and we find—

Height =	0^{ft}	5^{in}
Subtract from,	13	0
	12	7
Add 2 feet for Liverpool Charts, ...	2	0
Add *Admiralty* sounding, ...	11	0
Depth of water on bar at required time =	25	7

5. What was the depth of water at the Fairway Buoy, in the old Formby Channel, leading into Everton Channel and Formby Pool (Admiralty sounding $2\frac{1}{4}$ fathoms), at 5 P.M. of the 16th June, 1858?

(1). *Find time from high water.*

Time of high water.	2^h	50^m	P.M.
Subtract from, ...	5	0	
Time *after* high water,	2	10	

(2). *Find half range for day.*

High water	= 23^{ft}	10^{in}
Subtract, ...	13	0
Half range for day,	10	10

Entering Table II. with these numbers, we find—

Height, ...	5^{ft}	0^{in}
Add to, ...	13	0
	18	0
Add for Liverpool Chart, ...	2	0
Add for Admiralty sounding, ...	13	6
Depth of water at Fairway Buoy at given time =	33	6

6. The least Admiralty sounding in the bar of the Queen's Channel is $1\frac{1}{2}$ fathoms. Find the depth of water on this bar at 3 P.M. of the 20th November, 18—.

7. If the least depth of water on the Zebra bank be 3 feet, what was the depth at midnight of 1st April, 18—.

8. At the extreme low water of spring tides there is only one foot of water in the Rock Gut; at what hour of the afternoon of the 12th July, 18—, was there only 11 feet of water in this channel?

Adding 2 feet for the Liverpool Chart, as already explained, we have the bottom of the Rock Gut 3 feet below the zero of the Admiralty Tables, and are therefore required to find the time when there will be 8 feet of water above the Admiralty zero, and therefore 11 feet above the bottom.

Find the half range of tide for day.

High water	$= 26^{ft}$	5^{in}
Subtract, ...	13	0
Half range for day,	13	5

As the depth of water above mean low water is to be 8 feet, the figure required in the Table is 5 feet.

Half mean range	$= 13^{ft}$	0^{in}
Required depth, ...	8	0
Figure in Table,	5	0

Therefore enter the Table with $13\frac{1}{2}$ feet half range, and look for 5 feet in the horizontal column in the last three hours of the tide. It

is found between $3^h\ 37^m$ and $4^h\ 8^m$ after high water, and by proportional parts is found to be—

After high water, ...	$3^h\ 52^m$
Add time of high water, ...	0 11 P.M.
	4 3

Or the water had fallen to 11 feet in the Rock Gut at 3 minutes past 4 P.M. on the 12th July, 1858.

9. At extreme low water there are only 9 feet of water on the bar of Helbre Swatch. What was the depth of water at 1 A.M. of the 2nd November, 18—?

10. On the bar between the Welshman's Gut and the River Dee there are only 6 feet of water at low water of greatest spring tide. What was the depth of water on this bar at 4 P.M. of the 17th August, 18—?

11. What was the depth of water on the "four-fathom ledge," off Weston-super-Mare, at 8 P.M. of the 11th June, 18—?

(1). *Find time from high water.*

Time of high water, ...	$6^h\ 29^m$ P.M.
Subtract from, ...	8 0 P.M.
Time *after* high water,	1 31

(2). *Find half range for day.*

High water, ...	$36^{ft}\ 10^{in}$
Subtract half mean range, ...	18 7
Half range for day,	18 3

Entering Table II. with $1\frac{1}{2}$ hours and $18\frac{1}{4}$ feet, we find—

	$12^{ft}\ 11^{in}$
Add half mean range, ...	18 7
Add Admiralty sounding, ...	24 0
Depth of water at given time =	55 6

12. Find the depth of water on the "Tail Patch," off Weston-super-Mare, at 4 A.M. of the 16th December, 18—, the Admiralty sounding being 2 fathoms.

13. At low water there are 3¼ fathoms on the Mixon Shoal, off the Mumbles at Swansea. What will be the depth of water at four hours after high water at neap tides?

To answer this question you must turn to the Admiralty Tables, where you will find the range of neap tides at Swansea is 15 feet.

14. Find the depth of water above low water of ordinary springs at $2^h\ 41^m$ P.M. of the 17th July, 18—, at the intersection of the 16 feet curve of range with the X. o'clock cotidal line in the Irish Sea.

I.—To find the Change of Level of the Tide between two given hours, at a Port of Reference.

The rise or fall of the tide may be found by means of Galbraith and Haughton's Tidal Cards, as follows :—

Rule VI.

1. *Set the Ruler to the centre of the Clock-Card and the time of nearest High Water at the place ; and, if necessary, shift the Rulers until the two hours are laid open to view.*

2. *Apply the scale* B *to the Ruler, and shift the Card until its right edge cuts the hour which lies to the left. Holding the Card in its place, shift the Ruler until one of the marks on it coincides with the Zero of the scale.*

3. *Holding the Ruler in its place, slide the Card to the right until the edge cuts the other hour, and note the point on the upper line of the scale which lies opposite to the mark on the Ruler.*

4. *Lift the Card : stretch the thread over this point, and observe where it cuts the line corresponding to the Half Tide Range for the day.*

The distance marked off by the thread will be the number of feet in the rise or fall of the Tide.

If High or Low Water occurs between the given hours, the rise and fall, or *vice versâ*, may be obtained separately. The difference will be the effective rise or fall.

EXAMPLES.

1. To find the rise or fall of Tide at Liverpool between 2 P. M. and 7 P. M. on the 30th Oct., 1861.

High water, ... $8^h\ 25^m$ P. M.

Height of tide, ... $23^{ft}\ 4^{in}$
Half mean range, ... $13\ \ 0$

Half tide range for day, $10\ \ 4$

The distance run over on scale B is 34.2 divisions, which, transferred to the Half Tide Range of $10\frac{1}{2}$ feet, gives 18 feet rise.

The first hour being a little before low water, the level of the tide falls 3 inches, and then rises 18 feet 3 inches, giving an

Effective *rise* of Tide, ... 18 feet.

2. Find the rise or fall of Tide at Dover between $2^h\ 30^m$ P. M. and $4^h\ 50^m$ P. M., on the 16th May, 1861.

High water, ... $3^h\ 20^m$ P. M.

Height of tide, ... $15^{ft}\ 10^{in}$
Half mean range, ... $9\ \ 4$

Half tide range for day, $6\ \ 6$

The distance run over on the scale B is 4 divisions, which by the thread gives 1 ft. 4 in. on the Half Tide Range of $6\frac{1}{2}$ feet. Between $2^h\ 30^m$ and high water, and between high water and $4^h\ 50^m$, the distances run over are 2 and 6 divisions respectively, which correspond to 8 in. and 2 ft. respectively, showing an

Effective *fall* of Tide, ... 1 ft. 4 in.

3. Find the change of soundings between 7 A. M. and 10 A. M. on the 11th December, 1865, off Weston-super-Mare (H. W. $12^h\ 45^m$ P. M.; height of Tide 28 ft. 7 in.).

Ans. Rise, 11 ft. 2 in.

4. Find the fall of tide at Holyhead, from 2^h 10^m A. M. till 6^h 30^m A. M. of the 26th October 18—.

5. How high will the tide rise at Brest, from 1 P. M. till 4 P. M. of the 4th November, 18—?

K.—To find the Rise of Tide, or Height of High Water above Low Water of Spring Tides, at a Foreign Port, on a given day.

In the Admiralty Tide Tables the Rise of Tide, or height of high water above low water of springs, is given at many foreign ports, for springs and neaps, but not for intermediate days.

The Rise of Tide may be found for any day by the following Rule :—

Rule VII.

TO FIND THE RISE OF TIDE AT A FOREIGN PORT ON A GIVEN DAY.

1. *Subtract the Rise at neaps from the Rise at springs.*
2. *Enter Table V. with this difference, and with the age of the moon, reckoned from new or full.*
3. *Add to the number found in the Table the Rise at Neaps; and the sum will be the required Rise of Tide for the given day.*

EXAMPLES.

1. Find the Rise of Tide at Santa Cruz River on the 7th May, 1865.

From Admiralty Tide Tables, it is found that

Age of moon, ... 12th day after New.
Difference of springs and neaps, . 11 ft.

Entering Table V. with these numbers, we find,

1.04 ft.
Add 29.00 Rise at Neaps.

Ans. 30.04 ft.

2. Find the Rise of Tide at Noel anchorage, Bay of Fundy, on the 9th September, 1865.

Age of moon, ...	4th day after Full.
Difference of springs and neaps, .	7 ft.
From Table V. we find, ...	5.84
Add Rise at neaps, ...	43.50
Ans.	49.34 ft.

3. Find the Rise of Tide at Aden, on the 4th November, 1865.

Age of moon, ...	1st day after Full.
Difference of springs and neaps, .	$2\frac{1}{2}$ ft.

By Table V. we find,

For 2 ft., ...	1.98
" 3 ft., ...	2.97
	2)4.95
Mean, ...	2.47 ft.
Add Rise at neaps, ...	4.50
Ans.	6.97 ft.

4. Find the Rise of Tide at Rangoon, on the 15th March, 1865.

Age of moon, ...	3rd day after Full.
Difference of springs and neaps, .	7 ft.
From Table V., ...	6.33
Add Rise at neaps, ...	14.00
Ans.	20.33 ft.

5. Find the Rise of Tide at the mouth of the Yang-tse-kiang, on the 23rd August, 1865.

Age of moon, ... 2nd day after New.
Difference of Rise at springs and neaps, 5 ft.

From Table V., ...	4.77
Add Rise at neaps, ...	10.00
Ans.	14.77 ft.

In order to apply Table II. to find the depth of water, at a given hour, on a given day in a foreign port, we must know the time of high water, and range of tide for that day.

The mode of finding the time of High Water has been explained in Section G.

The range for the day may be found as follows :—

Rule VIII.

TO FIND THE RANGE OF TIDE ON A GIVEN DAY IN A FOREIGN PORT.

1. *Find by means of Table V. the number corresponding to the day and port.*

2. *Add the number so found to the difference between the Rise at neaps and half the Rise at springs.*

3. *Their sum is the half tide range for the day at the port.*

EXAMPLES.

Find the Ranges of Tide, for the days and places given in the last five examples.

1. Santa Cruz River, 7th May, 1865.

Rise at neaps, ...	29 ft.
Half Rise at springs, ...	20
Difference, ...	9
Add number found in Table V., . .	1.04
Ans.	10.04 half range.

2. Noel Anchorage, 9th September, 1865.

Rise at neaps, ...	43.50 ft.
Half Rise at springs, ...	25.25
Difference, . .	18.25
Add from Table V., ...	5.84
Ans.	24.09 Half tide range.

3. Aden, 4th November, 1865.

Rise at neaps, ...	4.50 ft.
Half Rise at springs, ...	3.50
Difference, ...	1.00
Add from Table V., ...	2.47
Ans.	3.47 Half tide range.

4. Rangoon, 15th March, 1865.

Rise at neaps, ...	14.00 ft.
Half Rise at springs, ...	10.50
Difference, ...	3.50
Add from Table V., ...	6.33
Ans.	9.83 Half tide range.

5. Yang-tse-kiang, 23rd August, 1865.

Rise at neaps, ...	10.00 ft.
Half rise at springs, ...	7.50
Difference, ...	2.50
Add from Table V., ...	4.77
Ans.	7.27 Half tide range.

6. Find the depth of water two hours after low water, on the bar of Rangoon River, on the 17th February, 1865, at a place marked 2 fathoms on the Chart.

Age of moon, ...	7th day after Full.
Difference of springs and neaps, .	7 ft.
From Table V., ...	3.85 ft.

Rise at neaps, ...	14 ft.
Half rise at springs, ...	10.50 ft.
Difference, ...	3.50 ft.
Add, ...	3.85
	7.35 Half tide range for Day.

Entering Table II. with $7\frac{1}{2}$ feet half range, and 4 hours from High Water, we find 3ft. 9 in., to be subtracted from half tide level:—

Half Rise at springs, . . .	10 ft.	6 in.
Subtract, . . .	3 "	9 "
	6	9
Add 2 fathoms, .	12	0
	18 ft.	9 in., depth of water required.

MISCELLANEOUS EXERCISES.

Mr. Towson, of Liverpool, has favoured us with Table III., and method of computing the depth of water to be added to the depth at low water of ordinary spring tides, for Liverpool and all places in the Irish Sea.

The first column in the Table gives the height of tide at Liverpool, as found in the Admiralty Tide Tables, the last column gives the corresponding height from Holden's Tide Tables, and the other columns give the height of water at any hour after high or before low water: the height thus found is to be added (with its proper sign) to the low water soundings of the charts.

N. B.—In the port of Liverpool itself the depths marked on the charts are to be increased by 2 feet.

Rule IX.

TO FIND THE DEPTH OF WATER TO BE ADDED TO THE SOUNDINGS MARKED ON THE CHART, AT ANY TIME AND PLACE IN THE IRISH SEA.

1. *Find from Plate IV. the hour of high water, full and change, at the ship's place.*

2. *Subtract this time from* $11^h\ 23^m$. *Subtract the difference from the time of high water at Liverpool on given day. The result is the time of high water at the given place. By means of this time of high water we can find the interval with which we must enter Table III.*

3. *To find the time of low water at any place, add $6^h\ 12^m$ to the preceding time of high water.*

4. *Enter Table III. with the time found as above, and the height at Liverpool in Admiralty Tables. The result thus found is the augmentation of soundings at Liverpool.*

5. *Find from Plate I. the range of spring tide at the given place.*

6. *As 30 feet : Range at given place : : Augmentation of soundings at Liverpool on given day : Required augmentation.*

If the time of high water for the given morning or afternoon be more than $6^h\ 12^m$, subtract $6^h\ 12^m$, and the remainder will be the time of low water required; but if the time of high water be less than $6^h\ 12^m$, add $6^h\ 12^m$, and the sum will be the time of low water. If the time of high water be less than $6^h\ 12^m$, and the sum be greater than 12 hours, there will be no low water for that morning or afternoon, as the case may be. If there be no high water during the morning or afternoon for which the time of low water is required, add 12 hours to the next tide, and subtract $6^h\ 12^m$, and the remainder will be the time of low water required.

The above rule, although not exact, is sufficiently approximate for any practical purpose.

EXAMPLES.

1. Required the time of low water at Dartmouth, on the morning of the 20th August, 1858.

High water at Devonport, ...	1^h	28^m	A.M.
Constant, ...	+0	33	
High water at Dartmouth,	2	1	A.M.
	6	12	
Low water at Dartmouth,	8	13	A.M.

2. Required the time of low water at Wicklow, on the afternoon of the 10th of January, 1858.

High water at Kingstown, ...	7^h	42^m	P.M.
Constant, ...	-0	41	
High water at Wicklow,	7	1	P.M.
	6	12	
Low water at Wicklow,	0	49	P.M.

3. Required the time of low water at Gravesend, on the afternoon of the 5th of October, 1858.

High water at London, ...	0^h	55^m	P.M.
Constant, ...	-0	57	

No afternoon high water at Gravesend.

High water at London, 6th October, . . .	1^h	17^m	A.M.
Constant, ...	-0	57	
High water at Gravesend, 6th October, .	0	20	A.M.
Add, ...	12	0	
	-6	12	
Low water at Gravesend, 15th October, .	6	8	P.M.

4. Required the time of low water at Cromarty, on the morning of the 8th January, 1858.

High water at Thurso, 8th Jan.	2^h	30^m A.M.	7th Jan.,	2^h	2^m	P.M
Constant, ...	$+3$	28		3	28	
High water at Cromarty, .	5	58		5	30	
Add, ...	6	12		6	12	
	12	10		11	42	P.M.
Subtract, ...	12	0				
Low water at Cromarty, . .	0	10 P.M.	No morning low water.			

We have already pointed out the necessity of distinguishing between the time of rise and fall of the tide, and that of the flow and ebb. These times in mid-

channel only agree at the "head of the tide," and in all other parts of the mid-channel the flow and ebb agree with the time of high and low water at "the head of the tide." In the Irish Channel, therefore, the flow commences about 18 minutes before the time of low water; and the ebb, 18 minutes before the time of high water in the Liverpool Tables. In the English Channel the times of the flow and ebb agree with the times of low and high water at Dover; but, for the purpose of augmenting the depth of water given in channel charts, it is necessary to determine the time of high water at the ship's place; for this purpose, in the Irish Channel, Liverpool should be regarded as the standard port, and in the English Channel, Dover. Plate IV. will give the time of high water, full and change, at the ship's place. Having thus determined the time of high water at the ship, if the given time be within $3^h\ 6^m$ of high water, enter Table III. with the time from high water at the top, and the height of tide in the Admiralty Tables in the left-hand column, or in Holden's on the right; the feet and inches thus given would be the augmentation at Liverpool for the given time from high water; but if the time from high water should exceed $3^h\ 6^m$, find the time of low water nearest to the given time, and enter the head of the Table with the time from low water, and one of the side columns, as before directed. The augmentation at Liverpool being thus determined, refer to the Tide Chart, Plate I.; the red curve nearest to the ship's place will give the range of the tide at the part of the channel for which the augmentation is required; then, by proportion, as 30 feet is to the range shown by the curve, so is the augmentation at Liverpool to the augmentation required. This augmentation may either be added to the depth given in the chart, or subtracted from the depth given by the lead line.

EXAMPLES.

1. Required the times of the commencement of ebb and flow on the morning of August 3rd, 1858, at 16 miles west of St. David's Head, and the feet and inches to be added to the depth given in the chart at 9^h 15^m A.M. of the same day.

High water at Liverpool, ...	4^h	12^m	A.M.
Subtract, ...	0	18	
Tide commences to ebb, ...	3	54	
	6	12	
Tide commences to flow, ...	10	6	
High water at Liverpool, full and change,	11^h	23^m	
Do. at ship's place, ...	5	0	
Constant, ...	− 6	23	
High water at Liverpool P.M. + 12 hours,	16	43	
High water at ship, ...	10	20	A.M.
Time given, ...	9	15	A.M.
Time *before* high water, ...	1	5	

Height of tide in Admiralty Table at Liverpool for August 3, A.M., 21^{ft} 8^{in}, with which, and 1 hour from high water, Table III. gives 20^{ft} 9^{in}, and the red curve in Plate I. gives 14 feet; then—

As 30 : 14 : : 20^{ft} 9^{in} : 9^{ft} 8^{in}

Ans. Augmentation 9^{ft} 8^{in}.

2. Required the commencement of ebb and flow on the afternoon of June 9th, 1858, at 20 miles north of Bardsey Island, and the augmentation of soundings, at 7^h 50^m P.M. of the same day.

High water at Liverpool, ...	9^h	10^m	P.M.
Subtract, ...	0	18	
Tide commences to ebb, ...	8	52	P.M.
	6	12	
Tide commences to flow, ...	2	40	P.M.

High water at Liverpool, full and change,	11	23	
Do. at ship's place, ...	9	0	
Constant, ...	−2	23	
High water at Liverpool, ...	9	10	
High water at ship, ...	6	47	P.M.
Time given, ...	7	50	P.M.
Time *after* high water, ...	1	3	P.M.

Height of afternoon tide at Liverpool for June 9, $24^{ft}\ 3^{in}$, with which and 1 hour from high water, Table III. gives $22^{ft}\ 11^{in}$. [But the ship's place is between the red curves of 15 feet and 16 feet in Plate I.]

Therefore, as $30^{ft} : 15^{ft}\ 6^{in} :: 22^{ft}\ 11^{in} : 11^{ft}\ 10^{in}$.

Ans. Augmentation $11^{ft}\ 10^{in}$.

3. Required the times of the commencement of ebb and flow on the morning of April 14, 1858, at 25 miles N.W. of Holyhead, and the feet and inches to be added to the depth given on the chart at 9.30 A.M. of the same day.

High water at Liverpool, ...	11^h	18^m	
Subtract, ...	0	18	
Tide commences to ebb, ...	11	0	A.M.
	6	12	
Tide commences to flow, ...	4	48	A.M.
High water at Liverpool, full and change,	11^h	23^m	
Do. at ship's place, ...	10	30	
Constant, ...	−0	53	
High water at Liverpool, ...	11	18	
Do. at ship, ...	10	25	A.M.
Time given, ...	9	30	
Time *before* high water, ...	0	55	

As $30^{ft} : 18^{ft} :: 25^{ft}\ 9^{in} : 15^{f}\ 5^{in}$, to be added to soundings given in the chart.

4. Required the times of the commencement of ebb and flow on the morning of October 7, 1858, at 25 miles west of the Calf of Man, and the feet and inches to be added to the depth given in the chart, at 5·30 P.M.

High water at Liverpool, ...	11^h	4^m	A.M.
Subtract, ...	0	18	
Tide commences to ebb, ...	10	46	A.M.
Tide commences to flow, ...	4	34	A.M.
High water at Liverpool, full and change, .	11^h	23^m	A.M.
Do at ship's place, ...	10	0	
Constant, ...	−1	23	
High water at Liverpool, ...	11	4	A.M.
	6	12	
Low water at Liverpool, ...	5	16	P.M.
Constant, ...	−1	23	
Low water at ship, ...	3	53	P.M.
Time given, ...	5	30	
Time *after* low water, ...	1	37	

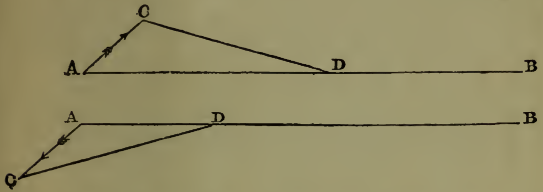
As $30^{ft} : 18^{ft} :: 2^{ft}\ 10^{in} : 1^{ft}\ 9^{in}$, to be added to the soundings in the chart.

Problem.

To find the course to steer in order to make good any course in a known current, and also the distance made good.

Draw a line on the chart representing the course to be made good; from the ship's place on the chart lay off a line in the direction of the set of the current, on which mark off from the ship's place the distance the current would set the ship in an hour; then take in the compasses the distance the ship logs in an hour, and put one foot on the last-named mark, and from the point where

the other foot reaches the first line draw a line to the mark on the line representing the direction of the current. The ship's head must be kept parallel to the last drawn line, and that portion of the first drawn line, intersected by the last drawn line, will be the distance the ship will make good per hour.



Let AB, in either figure, represent the course to be made good, AC the set of the current per hour, CD the distance the ship logs per hour. Then the ship's head must be kept parallel to the line CD, and AD will be the distance made good.

TABLE I.

RATE OF TIDAL STREAMS, AT ANY PERIOD BEFORE OR AFTER HIGH WATER AT THE HEAD OF THE TIDE.

Rate of Tidal Stream in Knots per Hour.	Time before or after High Water at the Head of Tide.											Rate of Tidal Stream in Knots per Hour.
	Hour. ½	Hour. 1	Hour. 1½	Hour. 2	Hour. 2½	Hour. 3	Hour. 3½	Hour. 4	Hour. 4½	Hour. 5	Hour. 5½	
¼	0·07	0·13	0·18	0·22	0·24	0·25	0·24	0·22	0·18	0·13	0·07	¼
½	0·13	0·25	0·35	0·43	0·48	0·50	0·48	0·43	0·35	0·25	0·13	½
¾	0·19	0·37	0·53	0·64	0·72	0·75	0·72	0·64	0·53	0·37	0·19	¾
1	0·26	0·50	0·71	0·86	0·96	1·00	0.96	0·86	0·71	0·50	0·26	1
1¼	0·33	0·63	0·89	1·08	1·20	1·25	1·20	1·08	0.89	0·63	0·33	1¼
1½	0·38	0·74	1·06	1·28	1·44	1·50	1·44	1·28	1·06	0·74	0·38	1½
1¾	0·45	0·87	1·24	1·50	1·68	1·75	1·68	1·50	1·24	0·87	0·45	1¾
2	0·52	1·00	1·42	1·72	1·92	2·00	1.92	1·72	1·42	1·00	0·52	2
2¼	0·59	1·13	1·60	1·94	2·16	2·25	2·16	1·94	1·60	1·13	0·59	2¼
2½	0·66	1·26	1·78	2·16	2·40	2·50	2·40	2·16	1·78	1·26	0·66	2½
2¾	0·71	1·37	1·95	2·36	2·64	2·75	2·64	2·36	1·95	1·37	0·71	2¾
3	0·78	1·50	2·13	2·58	2·88	3·00	2·88	2·58	2·13	1·50	0·78	3
3¼	0·85	1·63	2·31	2·80	3·12	3·25	3·12	2·80	2·31	1·63	0·85	3¼
3½	0·91	1·75	2·48	3·01	3·36	3·50	3·36	3·01	2·48	1·75	0·91	3½
3¾	0·97	1·87	2·66	3·22	3·60	3·75	3·60	3·22	2·66	1·87	0·97	3¾
4	1·04	2·00	2·84	3·44	3·84	4·00	3·84	3·44	2·84	2·00	1·04	4
4¼	1·11	2·13	3·02	3·66	4·08	4·25	4·08	3·66	3·02	2·13	1·11	4¼
4½	1·18	2·26	3·20	3·88	4·32	4·50	4·32	3·88	3·20	2·26	1·18	4½
4¾	1·23	2·37	3·37	4·08	4·56	4·75	4·56	4·08	3·37	2·37	1·23	4¾
5	1·30	2·50	3·55	4·30	4·80	5·00	4·80	4·30	3·55	2·50	1·30	5
Rate of Tidal Stream in Knots per Hour.	Hour. 5½	Hour. 5	Hour. 4½	Hour. 4	Hour. 3½	Hour. 3	Hour. 2½	Hour. 2	Hour. 1½	Hour. 1	Hour. ½	Rate of Tidal Stream in Knots per Hour.
	Time after or before Low Water at the Head of Tide.											

TABLE II.

HEIGHT OF THE TIDE ABOVE OR BELOW HALF TIDE FOR ANY GIVEN RANGE AND HOUR.

TIME FROM HIGH WATER.

Half range in feet and inches.	Add.							Subtract.							Half range in feet and inches.
	$0^h\ 0^m$	$0^h\ 31^m$	$1^h\ 2^m$	$1^h\ 33^m$	$2^h\ 4^m$	$2^h\ 35^m$	$3^h\ 6^m$	$3^h\ 6^m$	$3^h\ 37^m$	$4^h\ 8^m$	$4^h\ 39^m$	$5^h\ 10^m$	$5^h\ 41^m$	$6^h\ 12^m$	
ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. n	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
2 0	2 0	1 11	1 9	1 5	1 0	0 6	0 0	0 0	0 6	1 0	1 5	1 9	1 11	2 0	2 0
2 6	2 6	2 5	2 2	1 9	1 3	0 8	0 0	0 0	0 8	1 3	1 9	2 2	2 5	2 6	2 6
3 0	3 0	2 11	2 7	2 1	1 6	0 9	0 0	0 0	0 9	1 6	2 1	2 7	2 11	3 0	3 0
3 6	3 6	3 4	3 0	2 5	1 9	0 10	0 0	0 0	0 10	1 9	2 5	3 0	3 4	3 6	3 6
4 0	4 0	3 10	3 6	2 10	2 0	1 0	0 0	0 0	1 0	2 0	2 10	3 6	3 10	4 0	4 0
4 6	4 6	4 4	3 11	3 2	2 3	1 1	0 0	0 0	1 1	2 3	3 2	3 11	4 4	4 6	4 6
5 0	5 0	4 10	4 4	3 6	2 6	1 3	0 0	0 0	1 3	2 6	3 6	4 4	4 10	5 0	5 0
5 6	5 6	5 4	4 9	3 10	2 9	1 5	0 0	0 0	1 5	2 9	3 10	4 9	5 4	5 6	5 6
6 0	6 0	5 10	5 2	4 3	3 0	1 7	0 0	0 0	1 7	3 0	4 3	5 2	5 10	6 0	6 0
6 6	6 6	6 3	5 7	4 7	3 3	1 8	0 0	0 0	1 8	3 3	4 7	5 7	6 3	6 6	6 6
7 0	7 0	6 9	6 1	4 11	3 6	1 10	0 0	0 0	1 10	3 6	4 11	6 1	6 9	7 0	7 0
7 6	7 6	7 3	6 6	5 3	3 9	1 11	0 0	0 0	1 11	3 9	5 3	6 6	7 3	7 6	7 6
8 0	8 0	7 9	6 11	5 8	4 0	2 1	0 0	0 0	2 1	4 0	5 8	6 11	7 9	8 0	8 0
8 6	8 6	8 2	7 4	6 0	4 3	2 2	0 0	0 0	2 2	4 3	6 0	7 4	8 2	8 6	8 6
9 0	9 0	8 8	7 9	6 4	4 6	2 4	0 0	0 0	2 4	4 6	6 4	7 9	8 8	9 0	9 0
9 6	9 6	9 2	8 2	6 8	4 9	2 5	0 0	0 0	2 5	4 9	6 8	8 2	9 2	9 6	9 6
10 0	10 0	9 8	8 8	7 1	5 0	2 7	0 0	0 0	2 7	5 0	7 1	8 8	9 8	10 0	10 0
10 6	10 6	10 2	9 1	7 5	5 3	2 8	0 0	0 0	2 8	5 3	7 5	9 1	10 2	10 6	10 6
11 0	11 0	10 8	9 6	7 9	5 6	2 10	0 0	0 0	2 10	5 6	7 9	9 6	10 8	11 0	11 0
11 6	11 6	11 1	9 11	8 1	5 9	2 11	0 0	0 0	2 11	5 9	8 1	9 11	11 1	11 6	11 6
12 0	12 0	11 7	10 5	8 6	6 0	3 1	0 0	0 0	3 1	6 0	8 6	10 5	11 7	12 0	12 0
12 6	12 6	12 1	10 10	8 10	6 3	3 2	0 0	0 0	3 2	6 3	8 10	10 10	12 1	12 6	12 6
13 0	13 0	12 7	11 3	9 2	6 6	3 4	0 0	0 0	3 4	6 6	9 2	11 3	12 7	13 0	13 0
13 6	13 6	13 0	11 7	9 6	6 9	3 5	0 0	0 0	3 5	6 9	9 6	11 7	13 0	13 6	13 6
14 0	14 0	13 6	12 1	9 11	7 0	3 7	0 0	0 0	3 7	7 0	9 11	12 1	13 6	14 0	14 0
14 6	14 6	14 0	12 7	10 3	7 3	3 9	0 0	0 0	3 9	7 3	10 3	12 7	14 0	14 6	14 6
15 0	15 0	14 6	13 0	10 7	7 6	3 11	0 0	0 0	3 11	7 6	10 7	13 0	14 6	15 0	15 0
15 6	15 6	15 0	13 5	10 11	7 9	4 0	0 0	0 0	4 0	7 9	10 11	13 5	15 0	15 6	15 6
16 0	16 0	15 5	13 10	11 4	8 0	4 2	0 0	0 0	4 2	8 0	11 4	13 10	15 5	16 0	16 0
16 6	16 6	15 11	14 4	11 8	8 3	4 3	0 0	0 0	4 3	8 3	11 8	14 4	15 11	16 6	16 6
17 0	17 0	16 5	14 9	12 0	8 6	4 5	0 0	0 0	4 5	8 6	12 0	14 9	16 5	17 0	17 0
17 6	17 6	16 11	15 2	12 4	8 9	4 6	0 0	0 0	4 6	8 9	12 4	15 2	16 11	17 6	17 6
18 0	18 0	17 5	15 7	12 9	9 0	4 8	0 0	0 0	4 8	9 0	12 9	15 7	17 5	18 0	18 0
18 6	18 6	17 10	16 0	13 1	9 3	4 9	0 0	0 0	4 9	9 3	13 1	16 0	17 10	18 6	18 6
19 0	19 0	18 4	16 5	13 5	9 6	4 11	0 0	0 0	4 11	9 6	13 5	16 5	18 4	19 0	19 0
19 6	19 6	18 10	16 11	13 9	9 9	5 0	0 0	0 0	5 0	9 9	13 9	16 11	18 10	19 6	19 6
20 0	20 0	19 4	17 4	14 2	10 0	5 2	0 0	0 0	5 2	10 0	14 2	17 4	19 4	20 0	20 0
Half range in feet and inches.	$0^h\ 0^m$	$0^h\ 31^m$	$1^h\ 2^m$	$1^h\ 33^m$	$2^h\ 4^m$	$2^h\ 35^m$	$3^h\ 6^m$	$3^h\ 6^m$	$3^h\ 37^m$	$4^h\ 8^m$	$4^h\ 39^m$	$5^h\ 10^m$	$5^h\ 41^m$	$6^h\ 12^m$	Half range in feet and inches.
	Add.							Subtract.							

TIME FROM HIGH WATER.

TABLE III.

HEIGHT OF TIDE AT LIVERPOOL, ADAPTED TO THE ADMIRALTY AND HOLDEN'S TABLES.

Height at Liverpool, Admiralty Tide Tables.	Time from High Water.							Time from Low Water.							Height at Liverpool, Holden's Tide Tables.
	h. m. 0 0	h. m. 0 30	h. m. 1 0	h. m. 1 30	h. m. 2 0	h. m. 2 30	h. m. 3 0	h. m. 3 0	h. m. 2 30	h. m. 2 0	h. m. 1 30	h. m. 1 0	h. m. 0 30	h. m. 0 0	
ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
17 0	17 0	16 10	16 5	16 0	15 6	14 3	13 2	12 10	11 10	10 6	9 11	9 6	9 2	9 0	9 0
17 6	17 6	17 4	17 0	16 5	15 9	14 5	13 2	12 10	11 7	10 3	9 7	9 0	8 8	8 6	9 6
18 0	18 0	17 10	17 5	16 10	16 0	14 8	13 3	12 9	11 4	10 0	9 2	8 7	8 2	8 0	10 0
18 6	18 6	18 4	17 11	17 2	16 3	14 10	13 3	12 9	11 1	9 9	8 10	8 1	7 8	7 6	10 6
19 0	19 0	18 10	18 4	17 7	16 6	15 1	13 3	12 9	10 11	9 6	8 5	7 8	7 2	7 0	11 0
19 6	19 6	19 4	18 10	18 0	16 9	15 3	13 4	12 8	10 8	9 2	8 0	7 2	6 8	6 6	11 6
20 0	20 0	19 10	19 3	18 5	17 1	15 5	13 5	12 7	10 6	8 10	7 7	6 9	6 2	6 0	12 0
20 6	20 6	20 4	19 10	18 9	17 5	15 7	13 6	12 6	10 5	8 7	7 3	6 2	5 8	5 6	12 6
21 0	21 0	20 9	20 3	19 2	17 9	15 9	13 6	12 6	10 3	8 3	6 10	5 9	5 3	5 0	13 0
21 6	21 6	21 3	20 8	19 6	18 0	15 11	13 6	12 6	10 1	8 0	6 6	5 4	4 9	4 6	13 6
22 0	22 0	21 9	21 2	19 11	18 3	16 2	13 7	12 5	9 10	7 9	6 1	4 11	4 3	4 0	14 0
22 6	22 6	22 3	21 7	20 3	18 7	16 4	13 7	12 5	9 8	7 5	5 9	4 5	3 9	3 6	14 6
23 0	23 0	22 9	22 0	20 8	18 11	16 6	13 7	12 5	9 6	7 1	5 4	4 0	3 3	3 0	15 0
23 6	23 6	23 3	22 6	21 1	19 2	16 8	13 7	12 5	9 4	6 10	5 0	3 6	2 9	2 6	15 6
24 0	24 0	23 8	22 11	21 6	19 6	16 10	13 8	12 4	9 2	6 6	4 7	3 1	2 4	2 0	16 0
24 6	24 6	24 2	23 4	21 10	19 9	17 0	13 8	12 4	9 0	6 3	4 2	2 8	1 10	1 6	16 6
25 0	25 0	24 8	23 9	22 2	20 0	17 2	13 9	12 3	8 9	6 0	3 10	2 3	1 4	1 0	17 0
25 6	25 6	25 2	24 3	22 6	20 3	17 4	13 9	12 3	8 7	5 9	3 6	1 9	0 10	0 6	17 6
26 0	26 0	25 7	24 8	22 11	20 7	17 6	13 10	12 2	8 5	5 5	3 1	1 4	0 4	0 0	18 0
26 6	26 6	26 2	25 1	23 4	20 11	17 8	13 10	12 2	8 3	5 1	2 9	0 11	−0 2	−0 6	18 6
27 0	27 0	26 8	25 6	23 9	21 3	17 10	13 10	12 2	8 1	4 9	2 4	0 6	−0 7	−1 0	19 0
27 6	27 6	27 1	25 11	24 1	21 6	18 1	13 10	12 2	7 11	4 6	1 11	0 1	−1 1	−1 6	19 6
28 0	28 0	27 7	26 5	24 6	21 9	18 4	13 11	12 1	7 9	4 3	1 7	−0 5	−1 7	−2 0	20 0
28 6	28 6	28 1	26 10	24 10	22 0	18 6	13 11	12 1	7 6	3 11	1 2	−0 10	−2 1	−2 6	20 6
29 0	29 0	28 7	27 3	25 3	22 4	18 8	14 0	12 0	7 4	3 7	0 9	−1 3	−2 7	−3 0	21 0
29 6	29 6	29 1	27 8	25 8	22 8	18 10	14 0	12 0	7 2	3 4	0 5	−1 8	−3 0	−3 6	21 6
30 0	30 0	29 6	28 2	26 1	23 0	19 0	14 0	12 0	7 0	3 0	0 0	−2 2	−3 6	−4 0	22 0
Height at Liverpool, Admiralty Tide Tables.	h. m. 0 0	h. m. 0 30	h. m. 1 0	h. m. 1 30	h. m. 2 0	h. m. 2 30	h. m. 3 0	h. m. 3 0	h. m. 2 30	h. m. 2 0	h. m. 1 30	h. m. 1 0	h. m. 0 30	h. m. 0 0	Height at Liverpool, Holden's Tide Tables.
	Time from High Water.							Time from Low Water.							

TABLE IV.

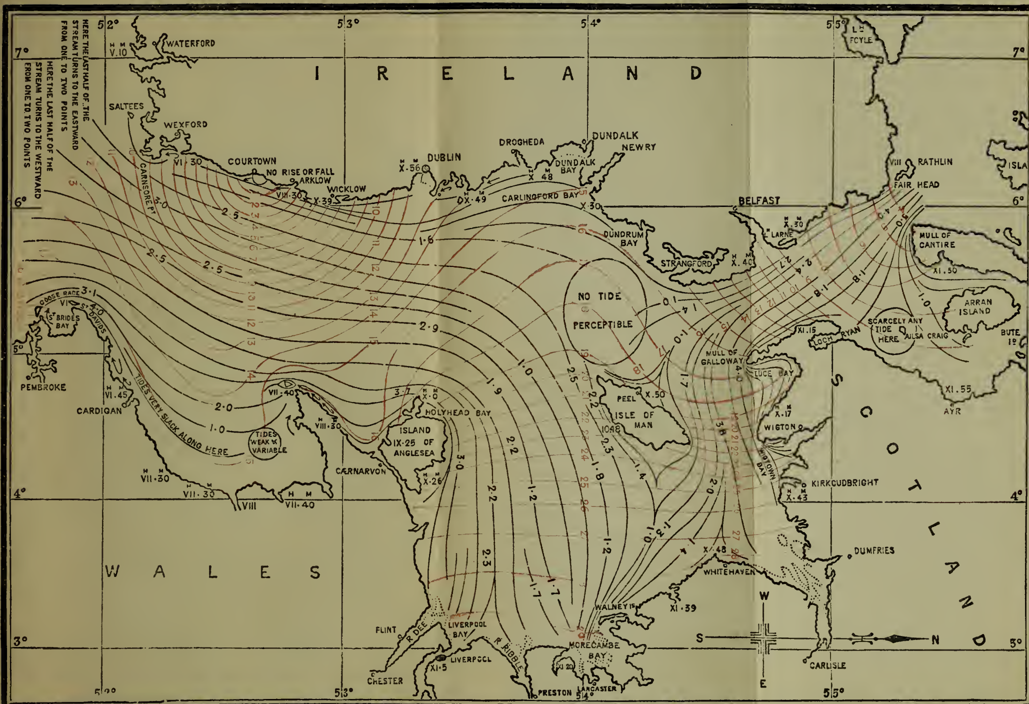
FOR THE REDUCTION OF THE TIME OF THE MOON'S PASSAGE OVER THE MERIDIAN OF GREENWICH, TO THE TIME OF ITS PASSAGE OVER ANOTHER MERIDIAN.

Longitude.	Daily Variation of the Moon's Passage.														Longitude.
	Subtract in East Longitude.													Add in West Longitude.	
	m. 40	m. 42	m. 44	m. 46	m. 48	m. 50	m. 52	m. 54	m. 56	m. 58	m. 60	m. 62	m. 64	m. 66	
0°	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0°
10°	1	1	1	1	1	1	1	1	1	2	2	2	2	2	10°
20°	2	2	2	2	3	3	3	3	3	3	3	3	3	4	20°
30°	3	3	4	4	4	4	4	4	4	5	5	5	5	5	30°
40°	4	4	5	5	5	5	6	6	6	6	6	7	7	7	40°
50°	5	6	6	6	6	7	7	7	7	8	8	8	9	9	50°
60°	6	7	7	7	8	8	8	9	9	9	10	10	10	11	60°
70°	7	8	8	9	9	9	10	10	10	11	12	12	12	12	70°
80°	9	9	9	10	10	11	11	12	12	12	13	13	14	14	80°
90°	10	10	11	11	12	12	13	13	13	14	14	15	15	16	90°
100°	11	11	12	12	13	13	14	14	15	15	16	17	17	18	100°
110°	12	12	13	14	14	15	15	16	16	17	18	18	19	19	110°
120°	13	14	14	15	15	16	17	17	18	19	19	20	20	21	120°
130°	14	15	15	16	17	17	18	19	19	20	21	21	22	23	130°
140°	15	16	17	17	18	19	20	20	21	22	22	23	24	25	140°
150°	16	17	18	19	19	20	21	22	22	23	24	25	26	26	150°
160°	17	18	19	20	21	21	22	23	24	25	26	26	27	28	160°
170°	18	19	20	21	22	23	24	25	25	26	27	28	29	30	170°
180°	19	20	21	22	23	24	25	26	27	28	29	30	31	32	180°
Longitude.	m. 40	m. 42	m. 44	m. 46	m. 48	m. 50	m. 52	m. 54	m. 56	m. 58	m. 60	m. 62	m. 64	m. 66	Longitude.
	Subtract in East Longitude.													Add in West Longitude.	
	Daily Variation of the Moon's Passage.														

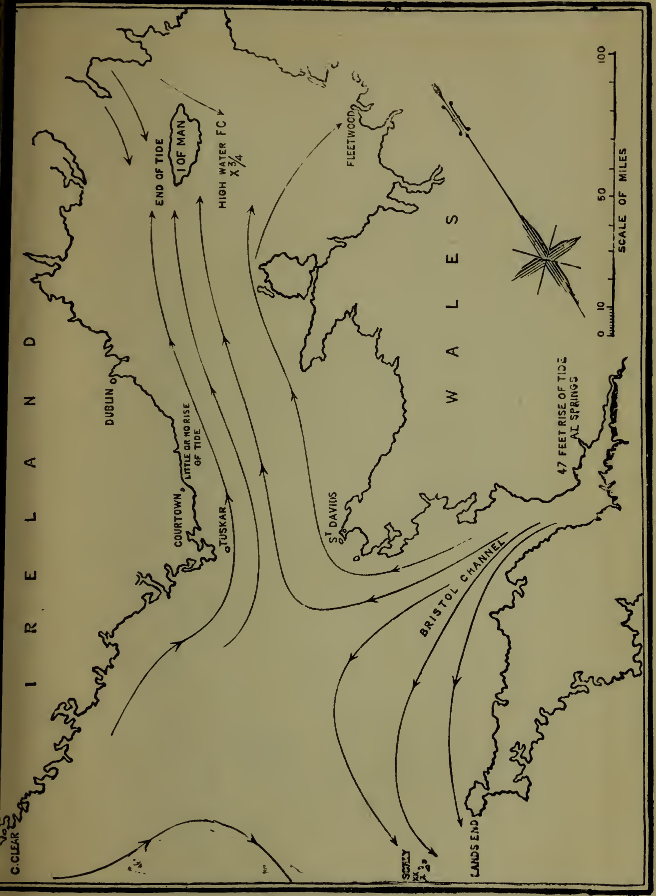
TABLE V.

TO FIND THE RISE OF TIDE ON A GIVEN DAY AT FOREIGN PORTS.

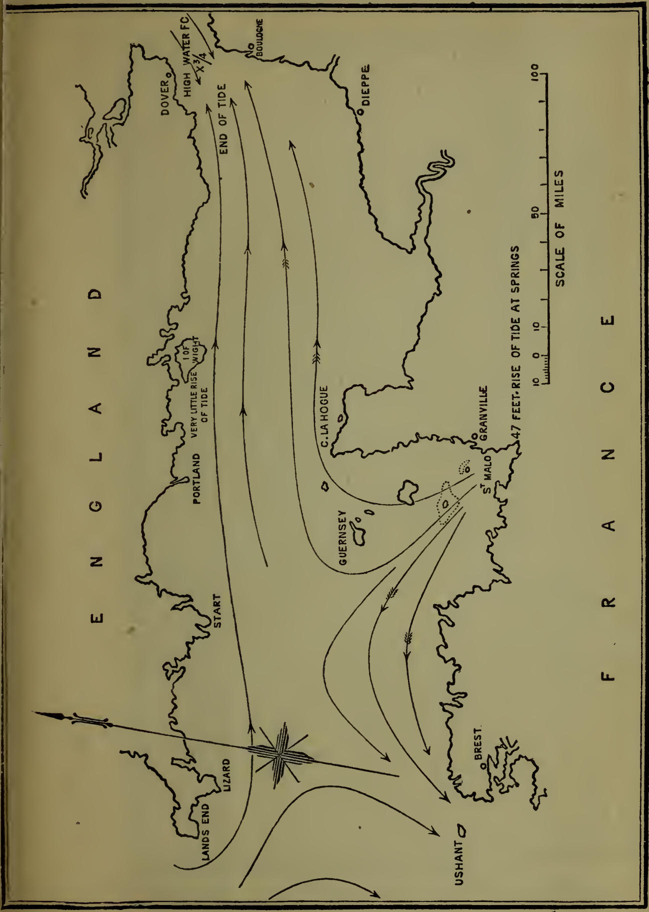
Day after New, or Full Moon.	Difference of Rise at Springs and Neaps.												Day after New, or Full Moon.
	1 foot.	2 feet.	3 feet.	4 feet.	5 feet.	6 feet.	7 feet.	8 feet.	9 feet.	10 feet.	11 feet.	12 feet.	
1st,	0.99	1.98	2.97	3.96	4.95	5.94	6.93	7.92	8.91	9.90	10.89	11.88	1st.
2nd,	0.95	1.91	2.86	3.82	4.77	5.73	6.68	7.64	8.59	9.55	10.50	11.46	2nd.
3rd,	0.90	1.81	2.71	3.62	4.52	5.43	6.33	7.24	8.14	9.05	9.90	10.86	3rd.
4th,	0.83	1.67	2.50	3.34	4.17	5.01	5.84	6.68	7.51	8.35	9.18	10.02	4th.
5th,	0.75	1.51	2.26	3.02	3.77	4.53	5.28	6.04	6.79	7.55	8.30	9.06	5th.
6th,	0.65	1.31	1.96	2.62	3.27	3.93	4.58	5.24	5.89	6.55	7.20	7.86	6th.
7th,	0.55	1.10	1.65	2.20	2.75	3.30	3.85	4.40	4.95	5.50	6.05	6.60	7th.
8th,	0.46	0.93	1.39	1.86	2.32	2.79	3.25	3.72	4.18	4.65	5.11	5.58	8th.
9th,	0.34	0.69	1.03	1.38	1.72	2.07	2.41	2.76	3.10	3.45	3.79	4.14	9th.
10th,	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	10th.
11th,	0.16	0.33	0.49	0.66	0.82	0.99	1.15	1.32	1.48	1.65	1.81	1.98	11th.
12th,	0.09	0.19	0.28	0.38	0.47	0.57	0.66	0.76	0.85	0.95	1.04	1.14	12th.
13th,	0.04	0.08	0.12	0.16	0.20	0.24	0.28	0.32	0.36	0.40	0.44	0.48	13th.
14th,	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	14th.
Day after New, or Full Moon.	1 foot.	2 feet.	3 feet.	4 feet.	5 feet.	6 feet.	7 feet.	8 feet.	9 feet.	10 feet.	11 feet.	12 feet.	Day after New, or Full Moon.
	Difference of Rise at Springs and Neaps.												



Tide Chart of the Irish Sea.



Tide Chart of the Southern Half of the Irish Channel.

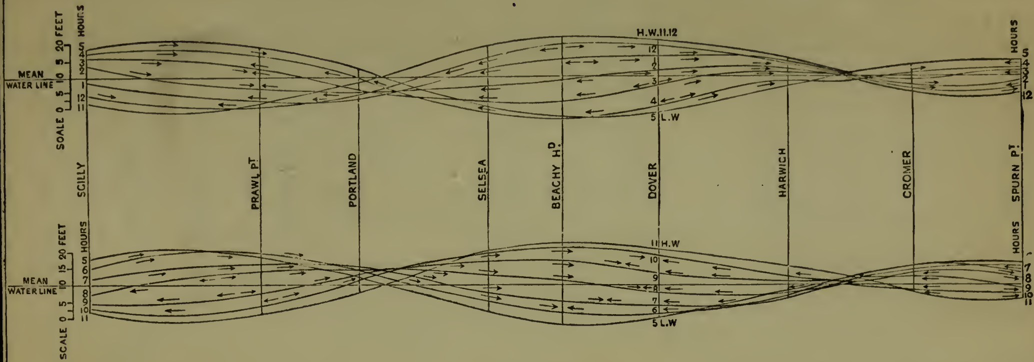


Tide Chart of the English Channel.

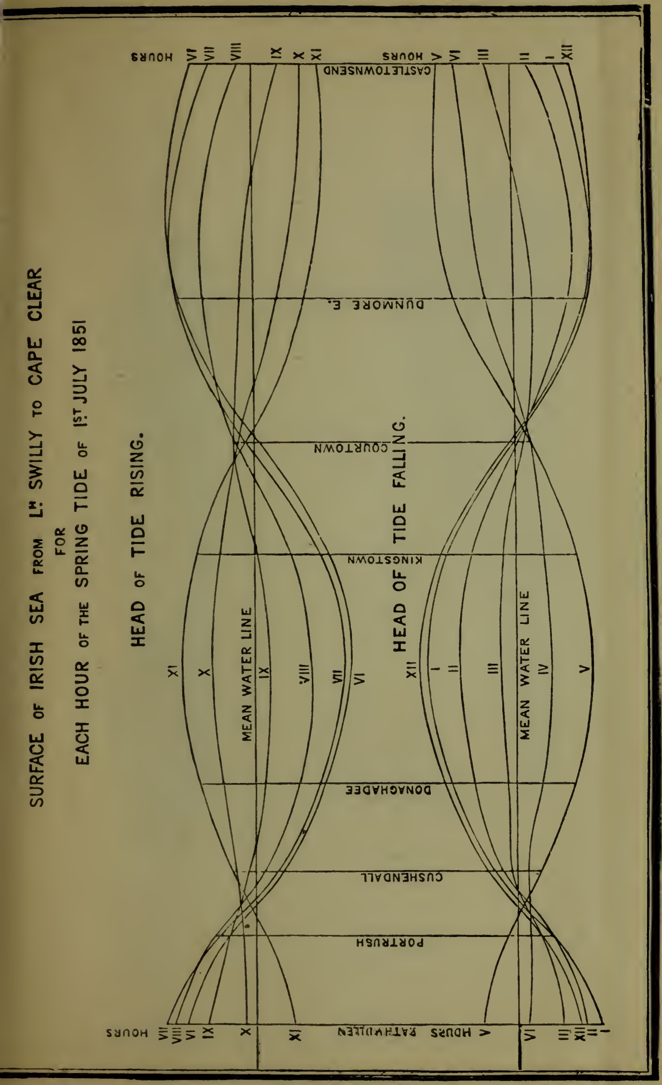
Cotidal Map of the British Islands.

SURFACE OF THE WATER AND DIRECTION OF THE STREAM BETWEEN SCILLY AND SPURN PT.
AT EACH HOUR OF THE TIDE

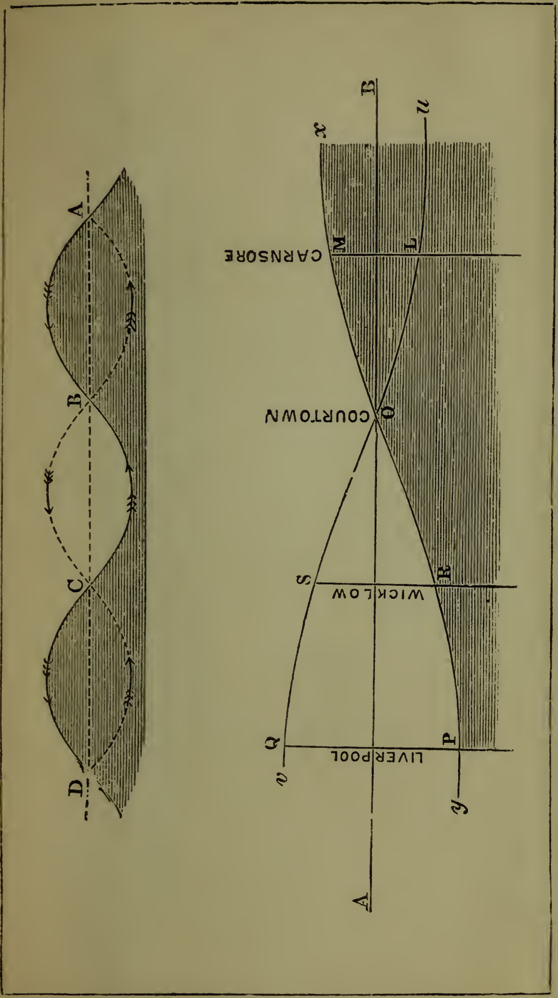
FALLING TIDES AT DOVER



RISING TIDES AT DOVER

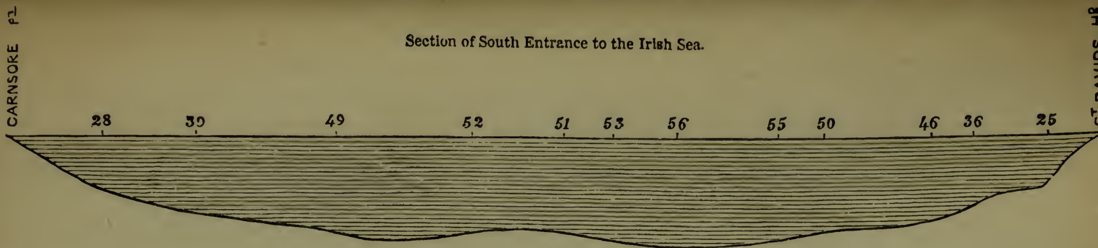


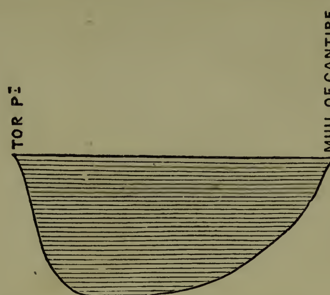
Tidal Wave on the East Coast of Ireland.



Tidal Diagrams.

Section of South Entrance to the Irish Sea.





Section of North Entrance to the Irish Sea.

Section of North and South Entrances to the Irish Sea, on the same Scale.